Appendix I

Pre-Experiment and First Steam Pass Water Characterization: Ions

Appendix I. Pre-experiment and first steam pass water characterization: Ions.

Date Sampled	Elapsed Time Days	Bicarbonate* mg/L	Carbonate* mg/L	Chloride mg/L	Hydroxide** mg/L	Nitrate-N mg/L	Ortho-Phosphate mg/L	Sulfate mg/L
TFF-I006-AQ								
1/11/93	***	370	<5	36	<5	<0.05	2.70	8
1/14/93	***	370	<5	42	<5	<0.05	0.30	5
1/22/93	***	380	<5	59	<5	0.34	0.01	6
2/19/93	22.04	170	<5	41	<5	<0.05	0.22	23
TFF-SEPE								
2/5/93	2.00	420	<5	56	<5	0.13	0.07	19
2/8/93	5.25	310	<5	50	<5	0.15	0.09	27
2/10/93	7.25	230	<5	41	<5	0.08	0.11	23
2/12/93	9.21	200	<5	33	<5	0.13	0.14	15
2/16/93	13.21	180	<5	35	<5	<0.05	0.14	21
2/19/93	16.21	160	<5	41	<5	<0.05	0.10	31
2/23/93	20.13	170	<5	41	<5	<0.05	0.05	32
2/25/93	22.04	170	<5	42	<5	<0.05	0.08	21
3/3/93	28.04	180	<5	55	<5	0.06	0.08	26
3/10/93	35.21	100	<5	28	<5	0.17	0.27	24
TFF-E006-AQ								
2/10/93	7.25	220	15	42	<5	<0.05	0.16	24
2/12/93	9.21	200	<5	33	<5	0.13	0.16	21
2/16/93	13.21	170	6	37	<5	<0.05	0.14	19
2/19/93	16.21	150	8	41	<5	<0.05	0.32	24
2/23/93	20.13	160	<5	41	<5	<0.05	0.11	26
2/25/93	22.04	160	<5	42	<5	<0.05	0.12	18
3/3/93	28.04	160	20	57	<5	0.46	0.11	21
3/10/93	35.21	93	<5	27	<5	0.17	0.18	24

Appendix I. Pre-experiment and first steam pass water characterization: Ions. (Continued).

Date Sampled	Elapsed Time Days	Bicarbonate* mg/L	Carbonate* mg/L	Chloride mg/L	Hydroxide** mg/L	Nitrate-N mg/L	Ortho-Phosphate mg/L	Sulfate mg/L
FH-416-BLRI								
2/5/93	2.00	<5	15	6	5	<0.05	<0.01	37
2/8/93	5.25	6	13	5	<5	<0.05	<0.01	34
2/10/93	7.25	12	6	4	<5	<0.05	<0.01	12
2/12/93	9.21	12	8	4	<5	<0.05	0.01	6
2/19/93	16.21	12	8	4	<5	<0.05	0.03	16
2/25/93	22.04	14	8	5	<5	<0.05	<0.01	5
3/3/93	28.04	14	<5	4	<5	0.05	<0.01	8
3/10/93	35.21	14	<5	3	<5	<0.05	<0.01	5
GP-PRESOFTER								
2/3/93	0.00	12	6	5	<5	0.06	<0.01	2
GP-POSTSOFTER								
2/3/93	0.00	30	20	4200	<5	0.87	0.05	46
GP-BLRON								
2/3/93	0.00	<5	<5	<1	<5	<0.05	0.02	2
2/5/93	2.00	<5	<5	<1	<5	<0.05	<0.01	4
2/8/93	5.25	6	<5	<1	<5	<0.05	<0.01	3
2/10/93	7.25	<5	<5	<1	<5	<0.05	<0.01	2
2/12/93	9.21	<5	<5	<1	<5	<0.05	0.02	<2
2/16/93	13.21	<5	<5	<1	<5	<0.05	0.02	<2
2/19/93	16.21	<5	<5	<1	<5	<0.05	0.04	<2
2/23/93	20.13	<5	<5	1	<5	<0.05	<0.01	13
2/25/93	22.04	<5	<5	<1	<5	<0.05	<0.01	<2
3/3/93	28.04	<5	<5	<1	<5	<0.05	<0.01	<2
3/10/93	35.21	<5	<5	<1	<5	<0.05	<0.01	<2
GP-BLROS								

Appendix I. Pre-experiment and first steam pass water characterization: Ions. (Continued).

Date Sampled	Elapsed Time Days	Bicarbonate* mg/L	Carbonate* mg/L	Chloride mg/L	Hydroxide** mg/L	Nitrate-N mg/L	Ortho-Phosphate mg/L	Sulfate mg/L
2/3/93	0.00	6	<5	<1	<5	<0.05	0.02	5
GP-POSTHTR								
2/3/93	0.00	12	6	5	<5	<0.05	0.04	8

*Measured as a function of calcium carbonate.

** Measured as a function of hydroxide ion.

*** Pre-experiment baseline or diagnostics data.

Analyses performed by Clayton Environmental Consultants, 1252 Quarry Lane, P.O. Box 9019, Pleasanton, CA, 94566

Appendix J

Pre-Experiment and First Steam Pass Water Characterization: Inorganics

Appendix J. Pre-experiment and first steam pass water characterization: Inorganics.

Date Sampled	Elapsed Time Days	Aluminum mg/L	Arsenic mg/L	Barium mg/L	Boron mg/L	Cadmium mg/L	Calcium mg/L	Chromium* mg/L	Copper mg/L	Iron mg/L	Lead mg/L	Magnesium mg/L	Manganese mg/L	Mercury mg/L	Nickel mg/L	Potassium mg/L	Selenium mg/L	Silver mg/L	Sodium mg/L	Zinc mg/L
TFF-I006-AQ																				
1/11/93	***	NR	NR	NR	NR	<0.001	NR	<0.005	0.006	0.19	NR	27.00	2.100	<0.0005	<0.0005	2.30	<0.005	<0.005	52.00	0.04
1/14/93	***	<0.02	0.006	0.36	NR	<0.001	64.00	<0.005	0.150	3.80	0.006	34.00	2.800	<0.0005	<0.0005	3.10	<0.005	<0.005	56.00	0.04
1/22/93	***	NR	NR	NR	NR	<0.001	NR	<0.005	0.011	0.44	NR	27.00	2.300	<0.0005	<0.0005	2.10	<0.005	<0.005	53.00	<0.01
2/19/93	22.04	0.10	0.008	0.18	2.00	<0.001	28.00	<0.005	0.034	0.11	0.004	8.60	0.460	<0.0005	<0.005	3.90	<0.005	<0.005	56.00	0.01
TFF-SEPE																				
2/5/93	2.00	0.35	0.007	0.33	NR**	<0.001	71.00	<0.005	0.010	0.37	<0.002	32.00	2.400	<0.0005	NR	1.90	<0.005	<0.005	67.00	<0.01
2/8/93	5.25	0.24	0.014	0.26	NR	<0.001	50.00	<0.005	0.058	0.28	0.009	21.00	1.400	<0.0005	NR	3.30	<0.005	<0.005	63.00	0.01
2/10/93	7.25	0.31	0.014	0.23	1.50	<0.001	40.00	<0.005	0.065	0.36	0.004	16.00	1.100	<0.0005	NR	3.90	<0.005	<0.005	59.00	<0.01
2/12/93	9.21	0.08	0.013	0.19	NR	<0.001	32.00	<0.005	0.200	0.07	0.009	12.00	0.740	<0.0005	NR	3.10	<0.005	<0.005	48.00	<0.01
2/16/93	13.21	0.04	0.009	0.16	1.30	<0.001	30.00	<0.005	0.190	0.02	0.004	10.00	0.480	<0.0005	NR	3.80	<0.005	<0.005	59.00	<0.01
2/19/93	16.21	0.03	0.007	0.17	1.80	<0.001	30.00	<0.005	0.200	0.03	0.004	9.20	0.500	<0.0005	<0.005	3.90	<0.005	<0.005	58.00	<0.01
2/23/93	20.13	0.03	0.007	0.18	1.70	<0.001	29.00	<0.005	0.380	0.02	0.003	9.10	0.480	<0.0005	<0.005	4.00	<0.005	<0.005	58.00	<0.01
2/25/93	22.04	0.02	<0.005	0.18	1.60	<0.001	31.00	<0.005	0.460	0.02	0.003	9.50	0.460	<0.0005	<0.005	4.10	<0.005	<0.005	59.00	<0.01
3/3/93	28.04	<0.02	0.010	0.21	1.50	<0.001	30.00	<0.005	0.320	0.02	0.004	9.70	0.550	<0.0005	<0.005	4.00	<0.005	<0.005	59.00	<0.01
3/10/93	35.21	0.84	0.013	0.12	1.70	<0.001	18.00	<0.005	0.230	0.77	0.005	5.60	0.150	<0.0005	<0.005	4.00	<0.005	<0.005	45.00	0.09
TFF-E006-AQ																				
2/10/93	7.25	0.15	0.015	0.24	1.50	<0.001	41.00	0.057	0.050	0.36	0.003	16.00	1.100	<0.0005	<0.005	4.00	<0.005	<0.005	59.00	<0.01
2/12/93	9.21	0.10	0.120	0.19	NR	<0.001	34.00	<0.005	0.160	0.10	0.002	13.00	0.760	<0.0005	NR	3.30	<0.005	<0.005	50.00	<0.01
2/16/93	13.21	<0.02	0.011	0.17	1.50	<0.001	31.00	<0.005	0.180	<0.01	<0.002	11.00	0.500	<0.0005	NR	3.90	<0.005	<0.005	59.00	<0.01
2/19/93	16.21	<0.02	0.006	0.17	1.80	<0.001	29.00	<0.005	0.180	<0.01	<0.002	9.20	0.490	<0.0005	<0.005	3.90	<0.005	<0.005	57.00	<0.01
2/23/93	20.13	<0.02	0.008	0.19	1.80	<0.001	31.00	<0.005	0.350	<0.01	<0.002	9.50	0.500	<0.0005	<0.005	4.20	<0.005	<0.005	62.00	<0.01
2/25/93	22.04	<0.02	0.006	0.19	1.70	<0.001	32.00	<0.005	0.440	<0.01	<0.002	9.80	0.490	<0.0005	<0.005	4.20	<0.005	<0.005	60.00	<0.01
3/3/93	28.04	<0.02	0.008	0.22	1.60	<0.001	33.00	<0.005	0.280	0.02	<0.002	10.00	0.570	<0.0005	<0.005	4.30	<0.005	<0.005	67.00	<0.01
3/10/93	35.21	0.20	<0.005	0.11	1.60	<0.001	16.00	<0.005	0.190	0.16	<0.002	5.10	0.130	<0.0005	<0.005	3.90	<0.005	<0.005	44.00	<0.01
FH-416-BLRI																				
2/5/93	2.00	0.03	<0.005	<0.01	<0.05	<0.001	5.20	<0.005	0.013	3.30	0.010	0.54	0.021	<0.0005	<0.005	<0.05	<0.005	<0.005	4.40	<0.01
2/8/93	5.25	0.03	<0.005	<0.01	<0.05	<0.001	4.80	<0.005	0.057	2.30	0.100	0.49	0.019	<0.0005	<0.005	<0.05	<0.005	<0.005	3.70	0.03
2/10/93	7.25	0.02	<0.005	<0.01	<0.05	<0.001	4.80	<0.005	<0.005	0.45	<0.002	0.37	0.007	<0.0005	<0.005	<0.05	<0.005	<0.005	3.30	<0.01
2/12/93	9.21	0.04	<0.005	<0.01	NR	<0.001	4.90	<0.005	<0.005	0.38	<0.002	0.40	0.007	<0.0005	NR	<0.05	<0.005	<0.005	3.50	<0.01
2/19/93	16.21	0.02	<0.005	<0.01	<0.05	<0.001	4.90	<0.005	0.140	1.80	0.058	0.38	0.014	<0.0005	0.005	<0.05	<0.005	<0.005	3.40	3.10
2/25/93	22.04	<0.02	<0.005	<0.01	<0.05	<0.001	6.20	<0.005	<0.005	0.29	<0.002	0.74	0.007	<0.0005	<0.005	<0.05	<0.005	<0.005	4.80	<0.01
3/3/93	28.04	0.02	<0.005	<0.01	<0.05	<0.001	4.90	<0.005	<0.005	0.75	<0.002	0.44	0.010	<0.0005	<0.005	<0.05	<0.005	<0.005	3.60	<0.01

Appendix J. Pre-experiment and first steam pass water characterization: Inorganics. (Continued).

Date Sampled	Elapsed Time Days	Aluminum mg/L	Arsenic mg/L	Barium mg/L	Boron mg/L	Cadmium mg/L	Calcium mg/L	Chromium* mg/L	Copper mg/L	Iron mg/L	Lead mg/L	Magnesium mg/L	Manganese mg/L	Mercury mg/L	Nickel mg/L	Potassium mg/L	Selenium mg/L	Silver mg/L	Sodium mg/L	Zinc mg/L
3/10/93	35.21	0.03	<0.005	<0.01	<0.05	<0.001	3.70	<0.005	0.057	0.14	0.020	0.38	0.013	<0.0005	<0.005	<0.05	<0.005	<0.005	3.50	0.02
GP-PRESOFTR																				
2/3/93	0.00	0.02	<0.005	<0.01	NR	<0.001	5.20	<0.005	0.005	0.12	<0.002	0.50	0.009	<0.0005	<0.005	NR	<0.005	<0.005	5.00	0.05
GP-POSTSOFTR																				
2/3/93	0.00	<0.02	<0.005	<0.01	NR	<0.001	7.10	<0.005	0.008	1.40	<0.002	1.50	0.012	<0.0005	<0.005	NR	<0.005	<0.005	2600.00	4.50
GP-POSTHTR																				
2/3/93	0.00	0.04	<0.005	<0.01	NR	<0.001	0.06	<0.005	0.027	2.10	0.063	<0.01	0.030	<0.0005	<0.005	NR	<0.005	<0.005	12.00	0.17
GP-BLRON																				
2/3/93	0.00	0.04	<0.005	0.07	NR	<0.001	1.10	<0.005	0.020	1.80	0.260	0.10	0.064	<0.0005	<0.005	NR	<0.005	<0.005	0.32	<0.01
2/5/93	2.00	0.05	<0.005	0.01	<0.05	<0.001	0.31	<0.005	0.039	0.31	0.100	0.04	0.033	<0.0005	<0.005	<0.05	<0.005	<0.005	0.37	<0.01
2/8/93	5.25	0.05	<0.005	<0.01	<0.05	<0.001	0.18	<0.005	0.031	0.16	0.440	0.06	0.010	<0.0005	<0.005	<0.05	<0.005	<0.005	4.20	<0.01
2/10/93	7.25	0.02	<0.005	0.03	<0.05	<0.001	0.17	<0.005	<0.005	0.06	0.030	0.02	0.018	<0.0005	<0.005	<0.05	<0.005	<0.005	0.16	<0.01
2/12/93	9.21	0.02	<0.005	0.02	NR	<0.001	0.17	<0.005	<0.005	0.06	0.031	0.01	0.015	<0.0005	NR	<0.05	<0.005	<0.005	0.21	<0.01
2/16/93	13.21	<0.02	<0.005	0.01	NR	<0.001	0.11	<0.005	<0.005	0.05	0.022	0.03	0.012	<0.0005	NR	<0.05	<0.005	<0.005	0.25	<0.01
2/19/93	16.21	0.03	<0.005	<0.01	<0.05	<0.001	0.50	<0.005	0.008	0.12	0.020	0.05	0.009	<0.0005	<0.005	<0.05	<0.005	<0.005	0.73	<0.01
2/23/93	20.13	0.02	<0.005	0.01	0.10	<0.001	0.31	<0.005	0.015	0.56	0.034	0.04	0.019	<0.0005	<0.005	<0.05	<0.005	<0.005	1.00	<0.01
2/25/93	22.04	<0.02	<0.005	<0.01	<0.05	<0.001	0.15	<0.005	0.052	0.12	0.030	<0.01	0.010	<0.0005	<0.005	<0.05	<0.005	<0.005	0.38	<0.01
3/3/93	28.04	<0.02	<0.005	<0.01	<0.05	<0.001	0.09	<0.005	<0.005	0.07	0.020	<0.01	0.007	<0.0005	<0.005	<0.05	<0.005	<0.005	0.13	<0.01
3/10/93	35.21	<0.02	<0.005	<0.01	<0.05	<0.001	0.12	<0.005	<0.005	0.06	0.015	0.02	0.007	<0.0005	<0.005	<0.05	<0.005	<0.005	0.14	<0.01
GP-BLROS																				
2/3/93	0.00	0.03	<0.005	0.08	NR	<0.001	0.96	<0.005	0.031	3.40	1.500	0.09	0.250	<0.0005	<0.005	NR	<0.005	<0.005	0.15	0.02

*Total.

**Not Requested

***Pre-experiment baseline or diagnostics data.

Analyses performed by Clayton Environmental Consultants, 1252 Quarry Lane, P.O. Box 9019, Pleasanton, CA, 94566

Appendix K

Pre-Experiment and First Steam Pass Water Characterization: Miscellaneous Analyses

Appendix K. Pre-experiment and first steam pass water characterization: Miscellaneous analyses.

Date Sampled	Elapsed Time Days	Alkalinity* mg/L	pH S.U.	Dissolved Organic Carbon mg/L	Total Dissolved Solids mg/L	Total Organic Carbon mg/L	Hardness** mg/L	Turbidity N.T.U.	Surfactants (MBAS) mg/L	Specific Conductance umhos/cm	Chemical Oxygen Demand mg/L
TFF-I006-AQ											
1/11/93	*****	370	7.5	NR	460	8	270	2.9	< 0.02	820	65
1/14/93	*****	370	7.7	NR	470	6	300	21.0	< 0.02	690	NR
1/22/93	*****	380	7.6	NR	500	2	260	6.0	0.02	910	23
2/19/93	22.04	170	6.7	3	390	4	110	2.0	0.09	490	NR
TFF-SEPE											
2/5/93	2.00	420	7.6	NR***	480	NR	310	NR	< 0.02	900	NR
2/8/93	5.25	310	7.2	NR	430	NR	210	NR	0.05	680	NR
2/10/93	7.25	230	6.8	3	390	4	170	7.6	0.04	570	NR
2/12/93	9.21	200	6.6	NR	340	NR	130	NR	0.07	480	NR
2/16/93	13.21	180	6.9	NR	350	NR	120	NR	0.06	470	NR
2/19/93	16.21	160	7.0	NR	390	NR	110	NR	0.09	470	NR
2/23/93	20.13	170	6.9	NR	380	NR	110	NR	0.12	480	NR
2/25/93	22.04	170	7.3	NR	400	NR	120	NR	0.14	450	NR
3/3/93	28.04	180	7.1	3	410	3	110	2.6	0.14	590	NR
3/10/93	35.21	100	6.9	NR	310	4	68	8.6	0.06	340	NR
TFF-E006-AQ											
2/10/93	7.25	240	8.5	11	420	12	170	8.8	0.20	570	NR
2/16/93	13.21	180	8.3	NR	370	NR	120	NR	0.10	490	NR
2/19/93	16.21	160	8.5	NR	400	NR	110	NR	0.15	470	NR
2/12/93	9.21	200	8.2	NR	350	NR	140	NR	0.18	480	NR
2/23/93	20.13	160	8.3	NR	410	NR	120	NR	0.17	480	NR
2/25/93	22.04	160	8.3	NR	450	NR	120	NR	0.21	150	NR
3/3/93	28.04	180	8.5	NR	430	NR	120	NR	0.17	550	NR
3/10/93	35.21	93	8.1	NR	320	NR	61	NR	0.11	350	NR
FH-416-BLRI											

Appendix K. Pre-experiment and first steam pass water characterization: Miscellaneous analyses. (Continued).

Date Sampled	Elapsed Time Days	Alkalinity* mg/L	pH S.U.	Dissolved Organic Carbon mg/L	Total Dissolved Solids mg/L	Total Organic Carbon mg/L	Hardness** mg/L	Turbidity N.T.U.	Surfactants (MBAS) mg/L	Specific Conductance umhos/cm	Chemical Oxygen Demand mg/L
2/5/93	2.00	20	9.4	NR	50	NR	15	NR	0.02	61	NR
2/8/93	5.25	19	9.6	NR	50	NR	14	NR	< 0.02	59	NR
2/10/93	7.25	18	9.5	ND	40	ND	14	1.2	< 0.02	56	NR
2/12/93	9.21	20	9.4	NR	40	NR	14	NR	0.04	50	NR
2/19/93	16.21	20	9.6	NR	30	NR	14	NR	< 0.02	54	NR
2/25/93	22.04	22	9.2	NR	50	NR	19	NR	0.03	66	NR
3/3/93	28.04	18	9.2	NR	50	NR	14	NR	0.02	62	NR
3/10/93	35.21	14	6.9	NR	30	NR	11	NR	< 0.02	44	NR
GP-PRESOFTR											
2/3/93	0.00	18	9.3	NR	30	NR	15	NR	< 0.02	64	NR
GP-BLRON											
2/3/93	0.00	< 5	7.5	NR	10	NR	3	NR	0.03	10	NR
2/5/93	2.00	< 5	8.2	NR	< 10	NR	<1	NR	<0.02	6	NR
2/8/93	5.25	6	9.3	NR	20	NR	<1	NR	< 0.02	12	NR
2/10/93	7.25	< 5	6.7	ND	10	ND****	<1	0.4	< 0.02	4	NR
2/12/93	9.21	< 5	7.0	NR	< 10	NR	<1	NR	0.03	3	NR
2/16/93	13.21	< 5	6.5	NR	< 10	NR	<1	NR	< 0.02	6	NR
2/19/93	16.21	< 5	7.3	NR	< 10	NR	1	NR	< 0.02	4	NR
2/23/93	20.13	< 5	7.0	NR	10	NR	<1	NR	0.03	15	NR
2/25/93	22.04	< 5	6.4	NR	< 10	NR	<1	NR	< 0.02	2	NR
3/3/93	28.04	< 5	6.3	NR	< 10	NR	<1	NR	0.03	7	NR
3/10/93	35.21	< 5	6.5	NR	< 10	NR	<1	NR	< 0.02	4	NR
GP-BLROS											
2/3/93	0.00	6	6.9	NR	10	NR	3	NR	0.03	12	NR

***Not requested.

****Not detected at or above the limits of detection.

*****Pre-experiment baseline or diagnostics data.

Analyses performed by Clayton Environmental Consultants, 1252 Quarry Lane, P.O. Box 9019, Pleasanton, CA, 94566

Appendix L

Second Steam Pass Water Characterization: Ions

Appendix L. Second steam pass water characterization: Ions.

Date Sampled	Elapsed Time Days	Bicarbonate* mg/L	Carbonate* mg/L	Chloride mg/L	Hydroxide** mg/L	Nitrate-N mg/L	Sulfate mg/L
TFF-SEPI							
6/11/93	19.08	180	<5	46	<5	<0.05	24
7/13/93	51.08	220	<1	52	<1	<5	17
TFF-E006-AQ							
6/11/93	19.08	NS	NS	NS	NS	NS	NS
7/13/93	51.08	210	20	53	<1	<5	18
FH-416-BLRI							
6/11/93	19.08	14	<5	6	<5	<0.05	3
7/13/93	51.08	16	<1	3	<1	<0.5	<1
GP-BLRON							
6/11/93	19.08	<5	<5	3	<5	<0.05	<2
7/13/93	51.08	NS***	NS	NS	NS	NS	NS

* Measured as a function of calcium carbonate.

** Measured as a function of hydroxide ion.

***Not sampled.

Analyses performed by California Laboratory Services, 3249 Fitzgerald Road, Rancho Cordova, CA, 95742.

Appendix M

Second Steam Pass Water Characterization: Inorganics

Appendix M. Second steam pass water characterization: Inorganics.

Date Sampled	Elapsed Time Days	Aluminum mg/L	Arsenic mg/L	Barium mg/L	Boron mg/L	Cadmium mg/L	Calcium mg/L	Chromium* mg/L	Copper mg/L	Iron mg/L	Lead mg/L	Magnesium mg/L	Manganese mg/L	Mercury mg/L	Nickel mg/L	Potassium mg/L	Selenium mg/L	Silver mg/L	Sodium mg/L	Zinc mg/L
TFF-SEPI																				
6/11/93	19.08	ANP**	ANP	ANP	ANP	ANP	29	ANP	0.24	0.04	ANP	9.7	0.45	ANP	ANP	ANP	ANP	ANP	61	<0.01
7/13/93	51.08	< 0.2	< 0.005	0.28	1.2	< 0.001	42	< 0.001	0.18	< 0.1	<0.005	14.0	0.56	< 0.0005	< 0.1	5	< 0.005	<0.001	74	<0.05
TFF-E006-AQ																				
6/11/93	19.08	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
7/13/93	51.08	< 0.2	< 0.005	0.29	1.3	< 0.001	43	< 0.001	0.29	< 0.1	<0.005	14.0	0.55	< 0.0005	< 0.1	5	< 0.005	<0.001	74	<0.05
FH-416-BLRI																				
6/11/93	19.08	ANP	ANP	ANP	ANP	ANP	4	ANP	< 0.005	0.66	ANP	0.6	0.01	ANP	ANP	ANP	ANP	ANP	5	0.09
7/13/93	51.08	< 0.20	< 0.005	< 0.05	0.1	<0.001	4	< 0.001	< 0.05	< 0.1	<0.005	< 0.5	< 0.03	< 0.0005	< 0.1	< 1	< 0.005	<0.001	3	<0.05
GP-BLRON																				
6/11/93	19.08	ANP	ANP	ANP	ANP	ANP	0		< 0.005	0.11	ANP	0.1	0.01	ANP	ANP	ANP	ANP	ANP	1	<0.01
7/13/93	51.08	NS***NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	

* Total.

** Analysis not performed by new contract laboratory.

*** Not sampled.

Analyses performed by California Laboratory Services, 3249 Fitzgerald Road, Rancho Cordova, CA, 95742.

Appendix N

Second Steam Pass Water Characterization: Miscellaneous Analyses

Appendix N. Second steam pass water characterization: Miscellaneous analyses.

Date Sampled	Elapsed Time Days	Alkalinity* mg/L	pH S.U.	Total Dissolved Solids mg/L	Hardness** mg/L	Specific Conductance umhos/cm	Surfactants (MBAS) mg/L
TFF-SEPI							
6/11/93	19.08	180	7.0	370	110	560	ANP***
7/13/93	51.08	220	7.6	420	410	580	<0.5
TFF-E006-AQ							
6/11/93	19.08	NS	NS	NS	NS	NS	NS
7/13/93	51.08	230	8.4	420	410	580	<0.5
FH-416-BLRI							
6/11/93	19.08	14	8.5	20	12	58	ANP
7/13/93	51.08	16	8.7	14	9	35	<0.5
GP-BLRON							
6/11/93	19.08	<5	7.3	<10	<5	20	ANP
7/13/93	51.08	NS****	NS	NS	NS	NS	NS

*Measured as a function of total alkalinity (calcium carbonate).

**Measured as a function of calcium carbonate.

*** Analysis not performed by new contract laboratory.

****Not sampled.

Analyses performed by California Laboratory Services, 3249 Fitzgerald Road, Rancho Cordova, CA, 95742.

Appendix O

Gasoline Concentrations (ppb) in Ground Water at the Gasoline Spill Area

Table O. Gasoline concentrations (ppb) in ground water at the Gasoline Spill area.

Sample Location	BTEX/TPH (7/92)	BTEX/TPH (1/93) £	BTEX/TPH (5/93)	BTEX/TPH (8/93)	BTEX/TPH (11/93)
GSW-001A	1,760 (11/90)/15,000	28,590/145,000	NS**	NS**	26,062/88,400
GSW-006	27,000/24,000 (8/90)	78,602/133,000	NS**	NS**	NS**
GSW-007	ND/ND*	ND/ND*	276/2700	71/1200	3/223
GSW-008	35/340 (8/91)	8/ND*	13/58	0.4/ND*	ND*/ND*
GSW-009	15/110 (9/91)	ND/ND*	4.6/29	Pump Broken	Pump Broken
GSW-010	3.2/150 (11/91)	NS**	Collapsed	Collapsed	Collapsed
GSW-011	1.6/90 (12/91)	NS**	15/140	688.2/2200	NS**
GSW-013	52 (8/90)/460 (8/90)	12/708	264/860	759/3700	865/1,840
GSW-208	175/960 (3/89)	NS**	NS**	NS**	16/2,350
GSW-215	10/170 (2/90)	9/55	9.5/107	215/250	NS**
GSW-216	200 (1/92)/760 (1/92)	130/1,710	26820/106000	50100/160000	3,906/25,800
MW-225	ND*/NA§	NS**	NS**	NS**	NS**
GSW-266	ND/ND* (9/87)	NS**	ND*/ND*	ND*/ND*	NS**
GSW-326	ND/ND* (8/89)	NS**	ND*/ND*	ND*/ND*	NS**
GSW-367	ND/ND* (9/87)	NS**	ND*/ND*	ND*/ND*	NS**
GSW-442	ND/ND* (9/87)	NS**	ND*/ND*	ND*/ND*	NS**
GSW-443	ND*/NA§	NS**	ND*/ND*	ND*/ND*	NS**
GSW-444	ND/ND*	NS**	ND*/ND*	ND*/ND*	NS**
MW-510	ND*/NA§	NS**	NS**	NS**	NS**
GEW-710	NA/NA§	80,380/177,000	NS**	NS**	NS**

§ Not Analyzed

* Not Detected

** Not Sampled

£ 50,000 to 100,000 gallons water injected into the formation during drilling operations

Appendix P

Minerals Present in Ground Water and Process Water at the Gasoline Spill Site

Appendix P. Minerals present in ground water and process water at the Gasoline Spill site.

Sample Description	Date	B	Fe	Mn	Ca	Mg	Na	SO4	pH	Hardness	Spec. Cond
GSW-001A	12/9/91			2.5							
	1/11/93	0.08	11	2.7	19	4.6	8.4	3	6.9	66	210
	11/12/93	0.8	<0.1	0.9	38	9.9	78		7.2	140	530
GSW-006	12/9/91			1.6							
	7/30/92	0.62	0.28	1.5	73	37	77	8	7.4	330	970
	1/13/93		27	0.52	22	12	43	11	7.7	100	420
GSW-007	4/24/86	0.25	<0.03	0.01	82	22	61	7	7.7	297	880
	12/10/91			0.2							
	7/30/92		0.19	0.2	73	34	62		7.7	380	900
	1/12/93	0.17	0.19	0.027	69	31	59	9	8	340	880
	5/18/93	0.14	1.5	0.56	110	35	46	14	7	350	1000
	11/12/93	0.24	<0.1	0.11	72	32	68		7.4	300	720
GSW-008	4/24/86	0.51	<0.30	<0.01	100	19	67		7.6		940
	12/10/91			0.15							
	7/30/92		0.44	0.14	80	33	66	28	7.5	340	970
	1/12/93	0.44	5.3	0.14	67	30	59	54	7.8	290	890
	5/18/93	0.46	4.7	0.16	84	32	63	72	7.4	340	960
	11/12/93	0.65	<0.1	<0.03	62	23	66		7.5	250	630
GSW-009	12/10/91			0.38							
	7/30/92		0.07	0.25	92	22	85	13	7.6	320	930
	1/12/93	0.76	0.6	0.078	45	15	61	36	7.7	170	630
GSW-013	12/10/91			0.12							
	1/12/93	0.66	16	0.19	17	27	74	43	8.8	150	660
	5/18/93	2.4	58	0.23	28	10	41	25	6.9	110	490
	11/12/93	1.7	<0.1	0.088	7.4	12	66		6.5	67	420
GSW-208	12/10/91			0.97							

Appendix P. Minerals present in ground water and process water at the Gasoline Spill site. (Continued).

Sample Description	Date	B	Fe	Mn	Ca	Mg	Na	SO4	pH	Hardness	Spec. Cond
	7/30/92		0.07	0.81	95	27	70	9	7.4	350	930
	11/12/93	0.29	<0.1	1.7	100	36	65		7.3	410	870
GSW-215	12/10/91			0.38							
	7/30/92		2	0.25	56	26	64	10	7.6	250	810
	1/12/93	0.59	0.23	0.02	56	24	65	15	7.9	240	790
GSW-216	12/10/91			0.79							
	1/12/93	0.33	4.4	0.84	58	27	75	18	8	260	860
	11/12/93	1.8	<0.1	0.63	79	23	83		6.8	290	820
GIW-814	8/5/92		1.3	0.069	66	34	85	16	7.7	300	790
	1/11/93	1	25	0.43	64	12	68	11	7.2	210	740
	11/12/93	1.7	<0.1	0.28	66	13	86		7.1	220	670
GIW-815	8/5/92		1.3	0.24	59	4.9	70	78	10.4	170	420
	11/12/93	4.5	<0.1	0.067	33	2.5	77		7.4	93	490
GIW-818	8/5/92		1.9	0.065	66	12	70	80	7.8	210	670
	11/12/93	5.3	0.74	0.61	22	3.2	100		6.8	68	560
GIW-819	8/5/92		2.1	0.18	54	29	99	28	7.8	250	780
	11/12/93	0.14	<0.1	0.45	5.4	<0.5	12		7.5	15	94
GIW-820	8/5/92		0.81	0.51	57	15	68	8	8.6	200	520
	11/12/93	3.6	<0.1	0.05	34	1.7	94		7.4	92	550
GEW-710	9/23/91	0.45	<0.1	0.77	89	40	91		7.5	410	850
	1/15/93	0.63	18	2.9	65	33	72	9	7.3	390	830

Appendix Q

Gasoline Volume Estimation

MEMORANDUM

TO:	Bill McConachie John Ziagos Dorothy Bishop	FROM:	Bob Devany
RE:	Gasoline Volume Estimates	DATE:	August 31, 1993

This memorandum documents our estimates of the mass/volume of gasoline in the subsurface prior to the start of the Dynamic Underground Steam Demonstration Project (DUSDP) at the Building 406 Gasoline Spill Area. Below we summarize the objectives, background, methodology, results and limitations of these estimates. Preliminary results of this work were presented in a memorandum to Bill McConachie dated March 25, 1993 and in part in a fax sent to John Ziagos on December 28, 1992.

Objectives

The objectives of this study are to use the best available data and techniques to characterize, in three-dimensions, the distribution, mass, and volume of gasoline in the subsurface at the Building 406 Gasoline Spill Area (GSA). Our work estimates the amount of gasoline in the subsurface after induced vapor venting by GSW-16 in the unsaturated zone and prior to beginning the DUSDP. The characterization relies extensively on the sediment chemical data from the 23 DUSDP boreholes drilled between January and April 1992. The estimate is intended to support numerical remediation modeling and to assist in LLNL's Environmental Restoration Division (ERD) management decisions regarding the DUSDP.

Background

Review of available records indicate that between 1952 and 1979 about 17,000 gallons of leaded gasoline may have been lost from the southernmost of four underground fuel tanks in the GSA. The accuracy of this inventory deficit is suspect since measurement accuracy is not known and undocumented removals may have occurred. Subsequent investigation indicates that a leak occurred at the western edge of the southernmost tank and gasoline is present in unsaturated sediment to a depth of about 100 ft and in saturated sediment and ground water to a depth of about 135 ft. Investigation of the spill has been comprehensive: two monitor wells and nine boreholes were drilled and sampled by Carpenter (1984); five monitor wells and six boreholes were drilled by O.H. Materials (1985); thirteen monitor wells were drilled in 1985 and 1986 (Dresen *et al.*, 1986) and ten additional monitor wells and two boreholes were drilled in 1987 (Nichols *et al.*, 1988). ERD installed eight single point and three multilevel soil vapor monitoring wells and one extraction well in 1991 (Macdonald *et al.*, 1991) In 1992, ERD and DUSDP jointly installed and sampled 23 additional boreholes.

Between September 1988 and December 1991 about 2,000 gal of liquid-equivalent gasoline was removed by ERD's induced venting pilot study in the unsaturated zone (Macdonald *et al.*, 1991). In addition, several hundred gallons of gasoline were removed by direct skimming and routine pumping during hydraulic tests and ground water sampling. An unknown amount of additional gasoline probably fluxed to the atmosphere. In addition, a microbiological study by Krauter and Rice (1991) indicated that subsurface microbiological populations at the GSA are much larger than those in nearby areas without gasoline suggesting that additional gasoline constituents have been metabolized by microbes. Thus, even assuming that the inventory discrepancy is accurate, post-spill processes make a mass/volume balance impossible.

The first estimate of gasoline volume in the subsurface at the GSA was conducted by Hunt *et al.* (1998) using sediment concentration data. Hunt indicated that, prior to venting, about 17,000 gal of gasoline were present in the subsurface. Because of data limitations (e.g., most samples were not analyzed for their total gasoline concentration), Hunt estimated total gasoline from measurements of the aromatic constituents benzene, ethylbenzene, toluene, and xylene (BETX). The ratio of measured BETX to total gasoline concentrations must have been assumed by Hunt since its proportion can vary significantly by manufacturer, date of production, and due to post-spill alterations (including biodegradation, oxidation and vaporization). The percentage of BETX used by Hunt to estimate total gasoline concentrations is not know to Weiss Associates.

In 1988, chemical data plotted on two chemical-based cross sections presented in Nichols *et al.* (1988) were used to further delineate the volume of gasoline present. Similar to Hunt, this estimate was conducted by reducing the observed distribution of gasoline and/or BETX to simple geometries (i.e., concentric cylinders) and assumed that the gasoline in sediments contained 16% BETX by weight. The results of this estimate were similar to Hunts, showing about 6,000 gal in the unsaturated zone and 11,000 gal in the saturated zone.

In 1990, ERD acquired the Interactive Volume Modeling (IVM) software by Dynamic Graphics, Alameda, California. Using a spline-type algorithm, this software interpolates scattered data onto a regular three-dimensional grid (hereinafter referred to as gridding) and creates 3-dimensional depictions of surfaces of equal concentration called iso-shells. The contour model can be viewed using a Silicon Graphics, Inc., workstation, allowing the user to slice and rotate the model to visualize the iso-shells and corresponding spatial distribution of property values such as concentration or porosity. IVM also calculates associated volumes of iso-shells in user-specified regions. The mass in each iso-shell (M_{is}) can be determined using the following equation:

$$M_{is} = V * D * C \quad \text{(Eq. 1)}$$

where

V = iso-shell volume

D = bulk density at the *in situ* moisture content

C = geometric mean of the iso-shell range

Total plume mass is the sum of all iso-shell masses. Specific to the GSA, gasoline volumes were calculated assuming a density of 0.75 mg/ml.

Prior to conducting this study, we reviewed IVM volumetric verification studies conducted by the Westinghouse Savannah River Company (Cope *et al.*, 1991) where concentric spherical iso-shells of known volume were gridded using IVM and volumes calculated. The input data mimicked typical environmental data by ranging over several orders of magnitude with sharp concentration gradients between iso-shells. However, due to the spherical geometry, the input data did not reflect typical chemical discontinuities resulting from the heterogeneous geological conditions typically present at LLNL. Cope's work showed that significant errors in volume occur when data values (i.e., chemical concentrations) are not logarithmically transformed prior to gridding. Cope also showed that additional errors (up to 7.3%) occurred in one of the spheres in log space. DGI responded to Cope's work with a demonstration that the these types of errors occurred due to numerical sensitivities (harmonics) within the interpolation algorithm triggered by Cope's analytically derived input data set, and demonstrated that the volumetrics were accurate to a tolerance of a few percent (Dynamic Graphics, 1991). However, DGI's and Cope's results confirmed that inappropriate grid selection and/or failure to log transform the data could result in volume errors exceeding 10% for simple, regular geometries.

In late 1991, we investigated IVM's gridding algorithm performance in areas of little or no data. Similar to Cope, we created an input data file consisting of the coordinates for several concentric spherical iso-shells with a steep concentration gradient between spheres. In log space, IVM's volume results were satisfactory, generally accurate within a few percent when gridded properly and similar to those results reported by Cope. However, when a quadrant of the input data was removed, the gridding algorithm created a bulge, increasing the actual volume of the sphere (Fig. 1). Thus, when using field data with a general spherical distribution, we expect that volumes will be increased in areas containing little or no data. Further sensitivity studies, though time consuming, are probably warranted to further explore the software's estimates of volume in areas of little or no data.

In 1992, Dynamic Graphics introduced a upgraded version of IVM called Geologic Modeling Program (GMP) (Dynamic Graphics, 1992). The gridding and volumetric algorithm remained unchanged from IVM and its results are comparable to the verified version of IVM.

Approach

Taking into account the above verification results and remediation history at the GSA, we developed the following approach for estimating gasoline volume:

- Use the post-venting sediment data above the water table and all available sediment data beneath the water table since the saturated zone has been largely unaffected by venting. Disregard post-sampling mass reductions due to biodegradation, surface flux, and routine sampling activities since it is not quantifiable. Assume that all sediment concentration data are reported in milligrams (mg) of gasoline (or BETX) per kilogram of sediment at *in-situ* moisture content. Also assume that 100% of the gasoline is extracted and quantified by the analytical laboratory.

- When available, use total gasoline analysis results. When only BETX concentrations are available, calculate the total fuel based on the average of site-specific ratios between all available total fuel and BETX measurements made on the same GSA sediment sample. Existing data indicate that total xylene is the most reliable indicator of total fuel at a value of 8% by weight (discussed below under Data Set).

- Convert data masked by analytical detection limits (i.e. a non-detections reported as < 50 mg/kg) to a value. In most cases non-detection points are given a value of zero. However if nearby data indicate that gasoline is probably present, use a value of one-half the detection limit.

- Log-transform the data.

- Use initial grid spacing of about one-half the average data spacing.

- Using GMP, interpolate the data onto a regular 3-dimensional grid. Because of differing spatial qualities and physical properties (i.e., bulk density) above and below the water table, use separate grids for these zones.

- Evaluate GMP's gridding statistics and resulting model. Re-grid, as necessary.

Data Set

The data set consisted of soil sediment concentration data from 66 boreholes and wells drilled between April 1985 and April 1992. Vadose zone sediment concentration data collected prior to January 1991 were omitted since significant mass/volume (i.e. 1,900 gal) was removed prior to this date by ERD's vapor extraction pilot study. This excludes the use of all of the Carpenter's (1984) data and large portions of the data collected by O.H. Materials (1985) and Dresen (1986).

Data collected after January 1991 include measurement of total gasoline (gasoline fingerprint). Prior to January 1991, however, gasoline fingerprint or total fuel analyses are sparse, with most samples analyzed only for BETX.

To identify whether BETX could be used as a reliable indicator of total fuel concentration, we used data from 57 pre-1992 samples where *both* BETX and total fuel were analyzed, and calculated the ratios individual aromatic constituents to total fuel concentrations (Table 1). As shown, xylene appears to be a reliable indicator of total fuel, since it occurs as a relatively high percentage of the total fuel and shows a favorable standard deviation and variance compared to benzene and toluene. We plotted xylene vs. total fuel (Fig. 2) which indicates that the relationship is linear and suggests an average content of about 8% xylene by weight. Using this xylene ratio, we processed the pre-1991 data to estimate the total fuel concentration. The data were then log-transformed. The resulting input data (btex31.asc) are included as Table 2.

Figure 3 shows a three-dimensional depiction of the input data set.

Results

Below we present volume results for two approaches. In the first approach, an interpolated method, the chemical data and DGI's interpolation algorithm were used. In preparing this model, judgement decisions were limited to the selection of the best gridding parameters based on visual and statistical evaluation of grid results. In

I:\JOBS\LLNL\BILL4.MEM

the second approach, the judgement/interpolated method, we merged the chemical data set with digitized isoconcentration contour lines from hand-contoured cross sections. Additional judgment decisions on the selection of the best gridding parameters were made using this approach based on visual and statistical evaluations of grid results.

Interpolated Approach

The processed data set (Table 2) was gridded with 28 grid nodes in the east-west direction, 32 grid nodes in the north-south direction and 120 grid nodes vertically (i.e., 28 X 32 X 120). The resulting grid was identified as btex4m.3grd. Dimensions of the model domain were 550 ft east-west (Laboratory coordinates (LC) 10,150 to 10,700), 430 ft north-south (LC 8,470 to 8,900) and 220 ft vertically (elevations 640 to 420). A corresponding graphical depiction of this grid yielded the model shown in Figures 4 and 5. As shown in Figure 4, the one ppm (log 0) shell shows limited horizontal spreading in the vadose zone and significant lateral spreading at depth in saturated sediments. Further analysis of Figure 5 indicates that most of the lateral spreading is in the lower steam zone at an elevation of about 530 ft. Figure 5 shows artifacts of gridding flaws (i.e., concentrations above 0.01 ppm in an area of no data where concentrations are suspected to be zero) in the north one-third of the model (LC > 8,750) below an elevation of 500 ft.

As shown in Table 3, the volume of gasoline in the vadose and saturated zone based on this model is about 2,269 gal. Based on the release history and former volume calculation, this volume is known to be erroneous. These erroneous results are expected, however, given the limited volume sampled compared to the total plume volume. Using the total plume volume estimates on Table 3, the volume sampled represents only 0.00015% of the total plume volume. The volume results are significant, however, in that they suggest that the bulk of the plume's mass and volume are contained within sediment containing more than 1 ppm total gasoline.

Judgement/Interpolated Approach

To help remedy the interpolation problem discussed above, we added judgement-based bias to the model by introducing data from hand-drawn isoconcentration contours completed on eight hydrostratigraphic cross sections. This approach greatly increases the number of input data points in important locations (i.e. > 1 ppm), and reduces the role of the computer-assisted interpolation while maintaining the use of GMP's volumetrics. To implement this approach, we developed a FORTRAN program to calculate the x,y,z coordinates of points digitized along isoconcentration contour lines to produce an input data file consisting of the original data (Table 1) plus the digitized concentration data. Because on the length of this file, it has not been included herein.

The processed data set (btex33.asc) was gridded separately for the vadose (44 X 35 X 72) and saturated zones (44 X 35 X 144). These grids were identified as btex10b.3grd and btex10a.3grd, respectively. Dimensions of the model domain were identical to the interpolated approach. This input data set is shown in three-dimensions in Figure 6 and 7 which also show a "wall" of points along the entire north side of the model. These points of 0 concentration are used to limit interpolation artifacts that would have otherwise occurred in areas of no data.

Graphical depictions of this grid are shown in Figures 8, 9, 10, and 11. When compared to the earlier model (Fig. 4), we note that 1 ppm iso-shell is significantly larger. Figure 9 shows a horizontal slice (cross section) in a similar location to Figure 5, which is traverses through the spill point near GSW-16. Figures 10 and 11 are horizontal slices showing the gasoline concentrations at the top of the water table and top of the lower steam zone, respectively.

The total gasoline volume for this model is 7,389 gal (Table 4). These results suggest that the judgement-based approach resulted in a more realistic model and enhanced the accuracy of the volume estimate. However, since an estimate of potential error is still not possible due to the interpolation, the volume results should be regarded as being only semi-quantitative.

DUSDP-Specific Volumes on Judgement/Interpolated Results

As part of the preliminary DUSDP performance evaluation process, we were asked by ERD to use the Judgement-based approach to estimate the amount of gasoline in several layers that may be affected by the DUSDP. Below we provide the quantity of gasoline by layer, and from the top of the upper steam zone to the bottom of the lower steam zone (i.e., the total volume). The first layer, 20 to 50 ft deep, represents the shallowest zone containing hydrocarbons and a zone with probable limited effect from the DUSDP since the top of the injection wells are deeper than 65 ft and the top of the extraction wells is about 50 ft deep. The second layer extends from 50 ft to the top of the upper steam zone, an irregular surface defined by the top of a hydrostratigaphic unit defined by Noyes (report in progress) for the DUSDP (Fig. 12). The third layer extends from the top of the upper steam zone to the water table at about 100 ft. As such, this layer represents the majority of what DUSDP has defined as the shallowest horizon for steam injection. The water table was picked as the lower boundary since it is a definable level (i.e., verses the capillary fringe) where pore spaces become liquid filled and the *in-situ* bulk density increases. The water table to the bottom of the lower steam zone, at depths between about 120 and 135 ft, comprises the fourth layer. A two dimensional surface was contoured to show the elevation of the bottom of the lower steam zone (Fig. 13). The fifth layer, the interval from the bottom of the upper steam zone to the top of the lower steam zone, is generally comprised of low permeability silt and clay. A contour map of the top of the lower steam zone (Fig. 14) was combined with the contour map of the bottom of the upper steam zone (Fig. 13) to model the volume of this layer. The final layer, the lower steam zone, is the deepest layer containing gasoline. The bottom of this layer is shown in Figure 15.

The final step for determining the volumes potentially affected by DUSDP was to limit the volumes using a polygon with apexes at the locations of the electrical heating/steam injection wells.

We estimate the total gasoline within the injection polygon to be:

1) 20-50 ft = 311 gal
2) 50 ft to the top of the upper steam zone = 642 gal
3) Upper steam zone (unsaturated) = 2938 gal
4) Upper steam zone (saturated) = 215 gal
5) Confining layer between the upper and lower steam zones = 1,963 gal
6) Lower steam zone = 480 gal
7) Total gasoline within the injection ring = 6,549

Supporting data and calculations for these estimates are included as Attachment 1.

Limitations

The limitations of the volume estimates described above are:

- The process requires judgement steps during gridding evaluation and in scattered data enhancement steps (i.e., cross-sections). The potential error resulting from this introduced bias cannot be quantitated, but it is estimated to be moderate, perhaps plus or minus 25%.

- The original input data are limited in number and spatial extent. Although interpolation relies on about 750 discrete soil concentration measurements from 66 boreholes, the total sample volume represents only 0.00015% of the total estimated plume volume. This represents an average spatial density of one data point for every 10,839 cubic feet of plume. The spatial density in the critical free-phase gasoline area is higher, but is still typically less than one sample per 100 cubic feet.

- Sediment chemistry data may not represent true in-situ concentrations because the sampling process compresses and heats the sample causing a net loss of gasoline. The highest measured pre- and post-venting gasoline concentration contains only 1.7% and 1.2% (i.e., 17,000 and 12,000 mg/kg) gasoline by weight, respectively, which is well below the theoretical concentration for a gasoline saturated sample (e.g., > 150,000 mg/kg).

- Sediment sample results are generally single point measurements and are not repeatable. The quantification of total gasoline requires the comparison to a standard of known concentration. However, the standard is generally modern fuel which may be compositionally different than the original and/or the "weathered" composition of the spilled gasoline .

- The number of samples collected in the vicinity of free-phase product may be too low. Miscalculation of the volume of free-phase product could skew the volume results significantly.

- The quantitation of potential errors due to lack of data in certain areas and gridding decisions is impossible to determine. Significant sensitivity and spatial statistical evaluation may be required to evaluate these errors.

Conclusions

The methodology described above is a valuable method for visualizing the subsurface distribution of contaminants in the subsurface. However, its volumetrics calculations are limited by the sample density, potentially unreliable chemical data and judgement-based bias introduced during interpolation. Judgment-based data enhancement or the combining of data sets (i.e., chemistry and geology) is generally necessary to increase the amount of input data to the interpolator and the resulting validity of the model.

The volume estimates presented herein should be regarded as semi-quantitative. In some instances, a highly refined model my be used semi-quantitatively to compare relative volumes in different zones. Future steps for improvement might include the use of spatial statistics (kriging) and conditional simulation.

I:\JOBS\LLNL\BILL4.MEM

List of Figures

List of Tables

References

Carpenter, D.W., (1984), *Assessment of Contamination in Soils and Groundwater at the Lawrence Livermore National Laboratory, Sandia National Laboratory, and Adjacent Properties*, Lawrence Livermore National Laboratory, Livermore California (UCAR-10180)

Cope, C.D. and B.B. Looney (1991), Interoffice Memorandum to C.A. Eddy dated July 9, 1991. Westinghouse Savannah River Company.

Dresen, M.D, F. Hoffman, and S. Lovejoy, Jr. (1986), *Subsurface Distribution of Hydrocarbons in the Building 403 Area at LLNL*, Lawrence Livermore National Laboratory, Livermore, Calif. (UCID-20787)

Dynamic Graphics, Inc. (1991) Analysis of the Savannah River Volumetric Test using IVMCalc 4.0. Internal report dated September 17, 1991, Dynamic Graphics, Inc., Alameda, Calif.

Dynamic Graphics, Inc. (1992), *Geologic Modeling Program (GMP)*, Dynamic Graphics, Inc., Alameda, Calif.

Hunt, J.R., J.T. Geller, N. Sitar, and K.S. Udell (1988), *Subsurface Transport Processes for Gasoline Components*, Submitted to the Canadian Society of Civil Engineers, American Society of Civil Engineers July 1988 Meeting, Vancouver, B.C.

Krauter and Rice (1991)

O.H. Materials (1985), *Site Investigation, Hydrocarbon Leak Near Building 403*, Lawrence Livermore National Laboratory, Livermore, Calif., unpublished consultants' report to LLNL dated August 12, 1985.

Macdonald, J. K., et al. (Eds.) (1991), *LLNL Ground Water Project 1991 Annual Report*, Lawrence Livermore National Laboratory, Livermore, Calif. (UCAR-10160-91-12)

Nichols, E.M., M.D. Dresen, J.E. Fields (1988), *Proposal for Pilot Study at LLNL Building 403 Gasoline Station Area*, Lawrence Livermore National Laboratory, Livermore, Calif. (UCAR-10248)

FIGURES

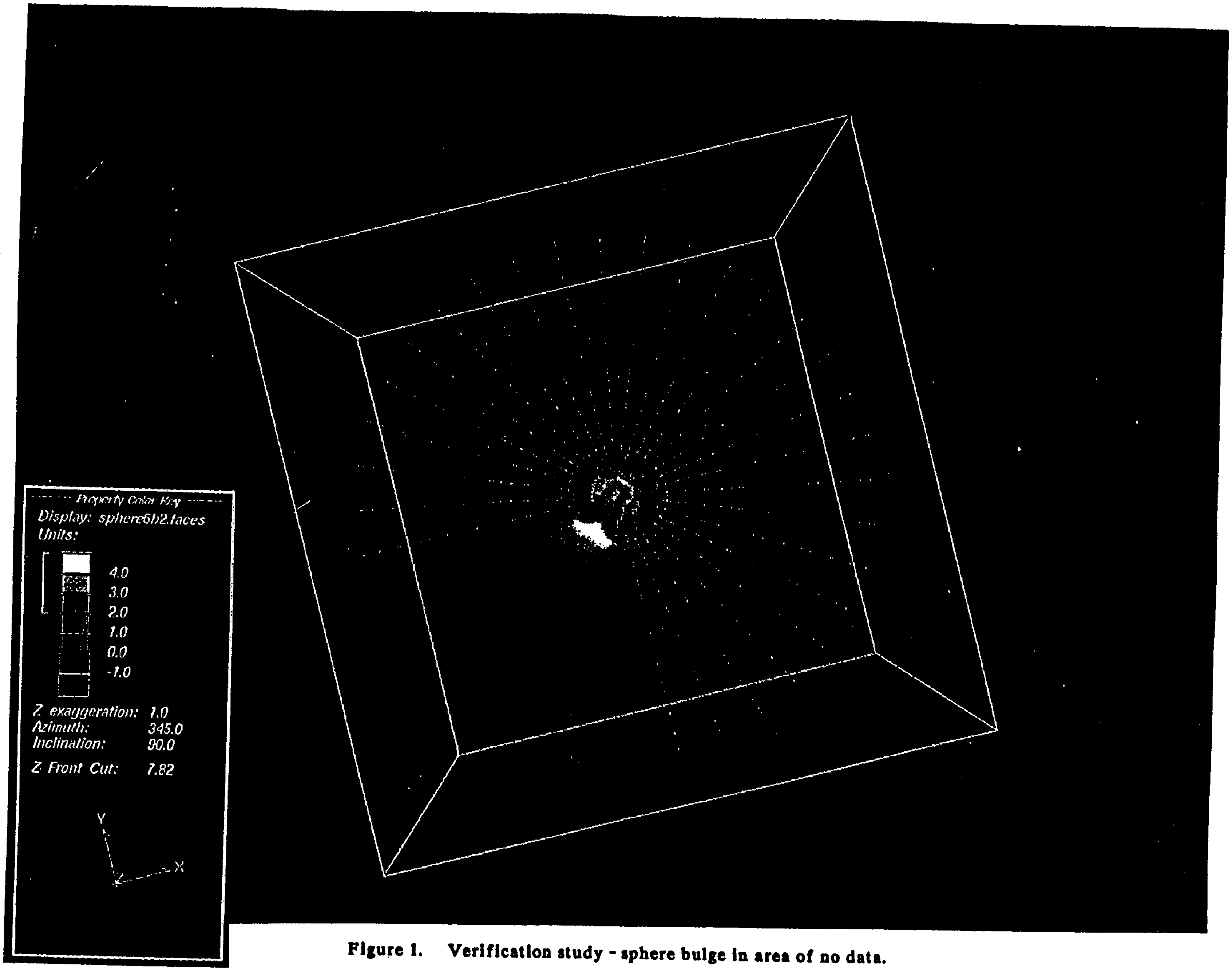


Figure 1. Verification study - sphere bulge in area of no data.

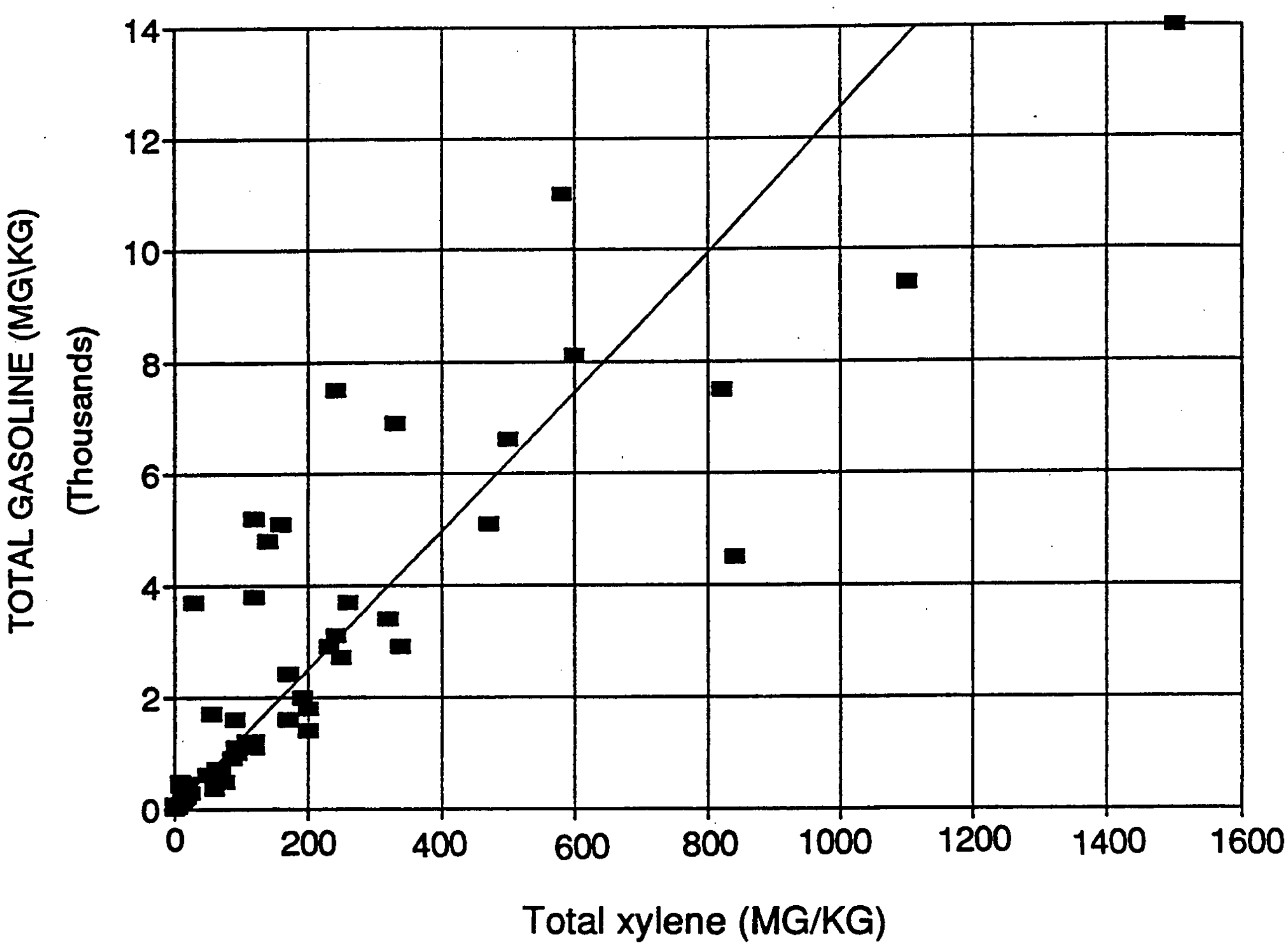


Figure 2. **Xylene verses total fuel concentration for 57 GSA sediment samples.**

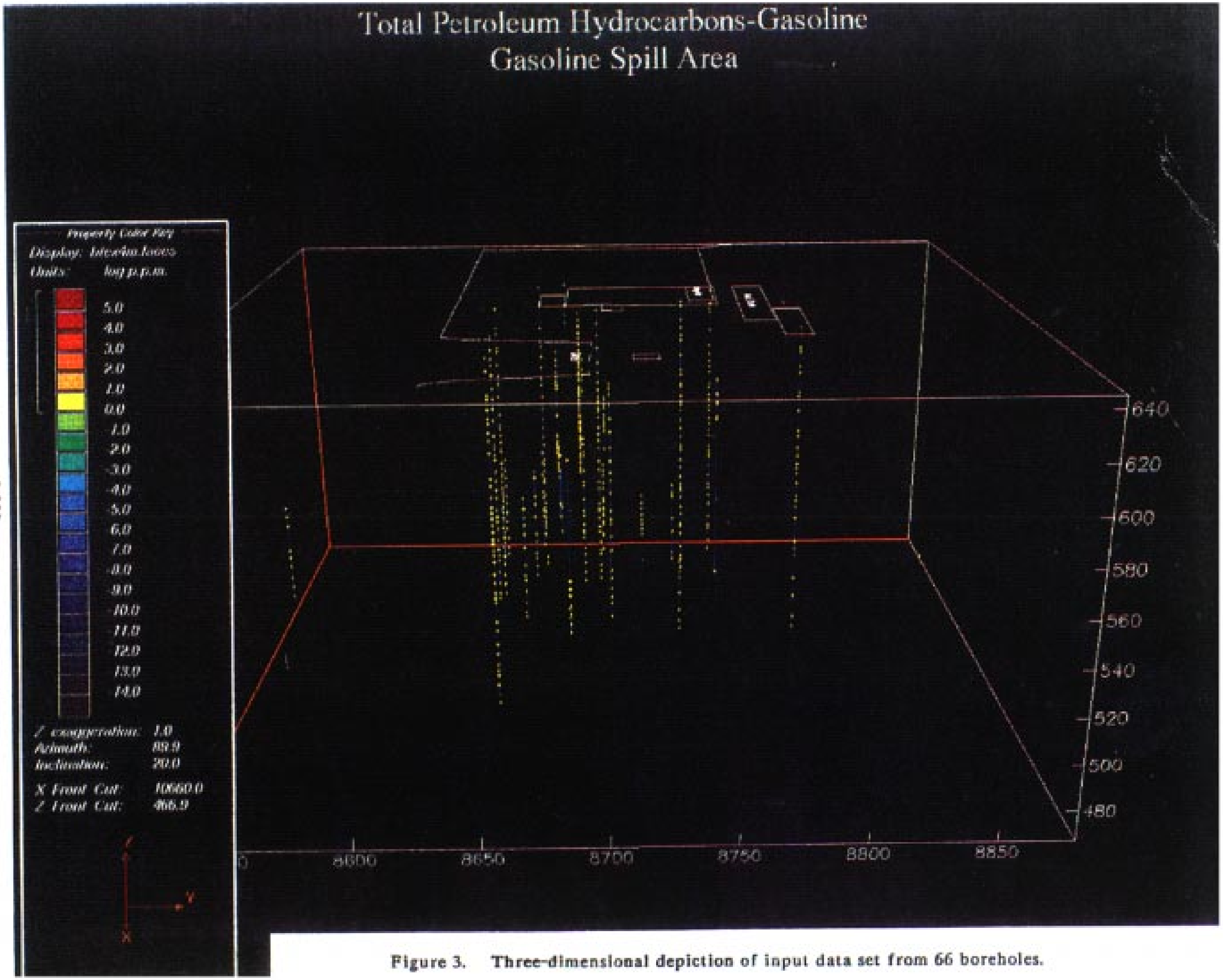


Figure 3. Three-dimensional depiction of input data set from 66 boreholes.

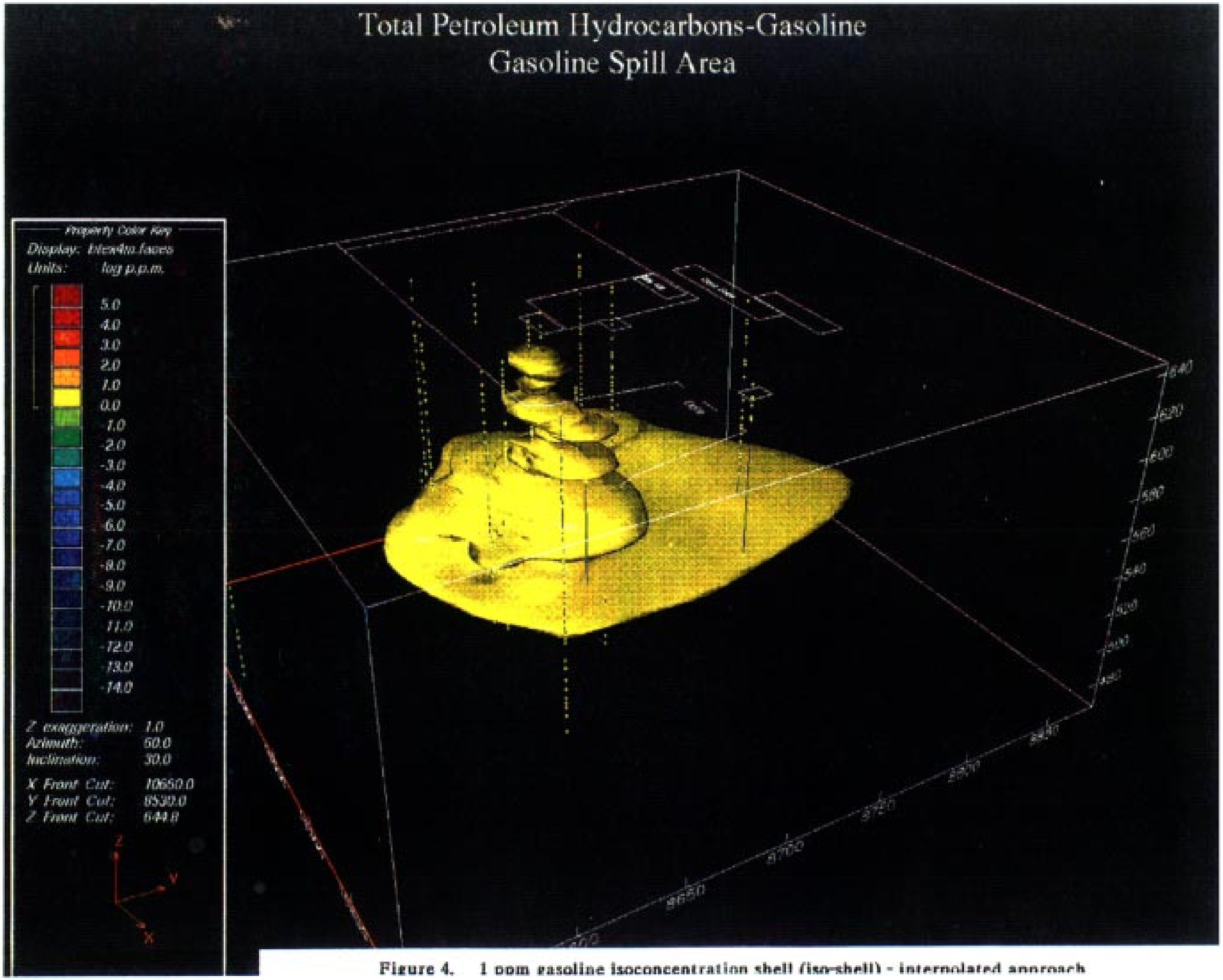


Figure 4. 1 ppm gasoline isoconcentration shell (iso-shell) - interpolated approach

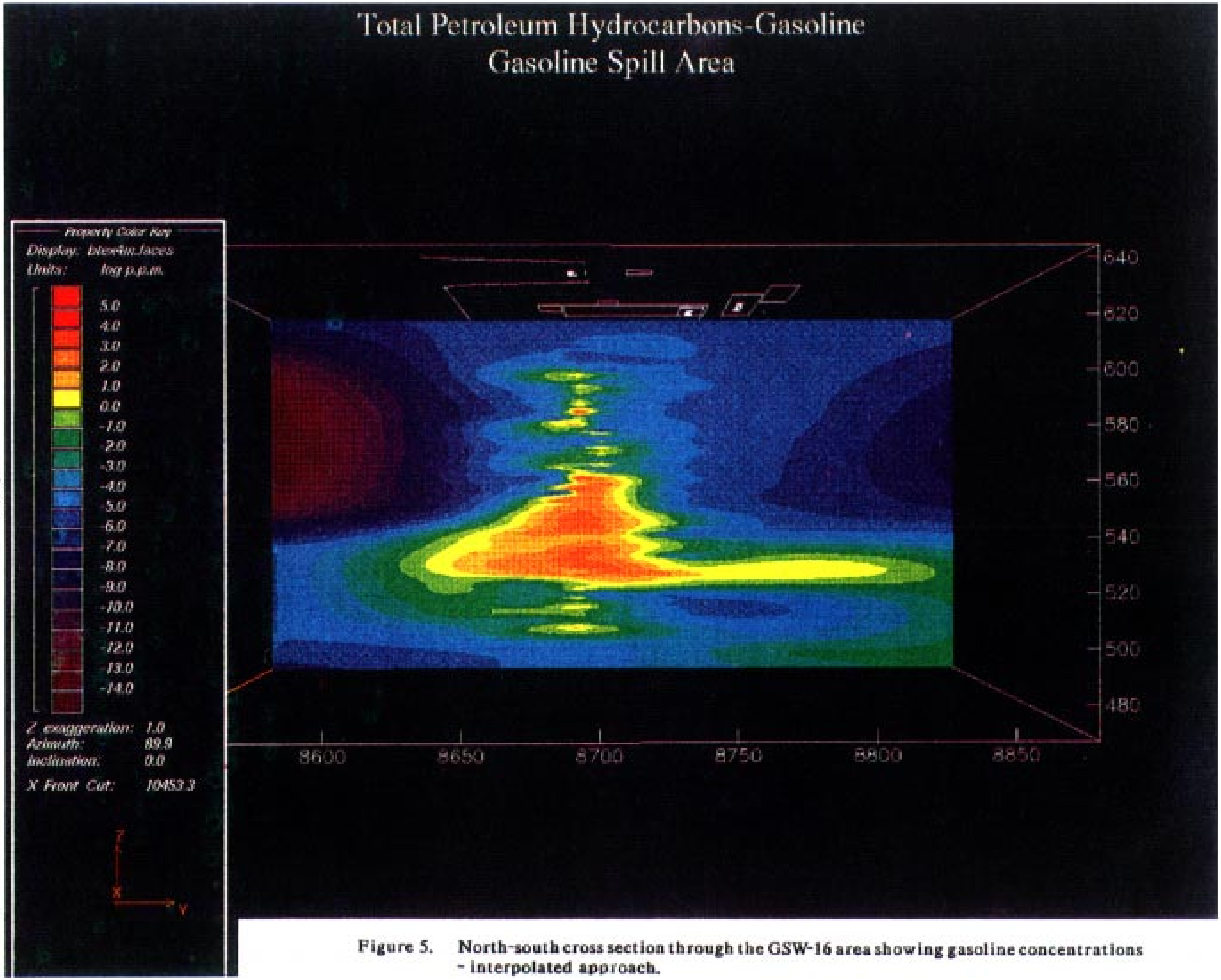


Figure 5. North-south cross section through the GSW-16 area showing gasoline concentrations - interpolated approach.

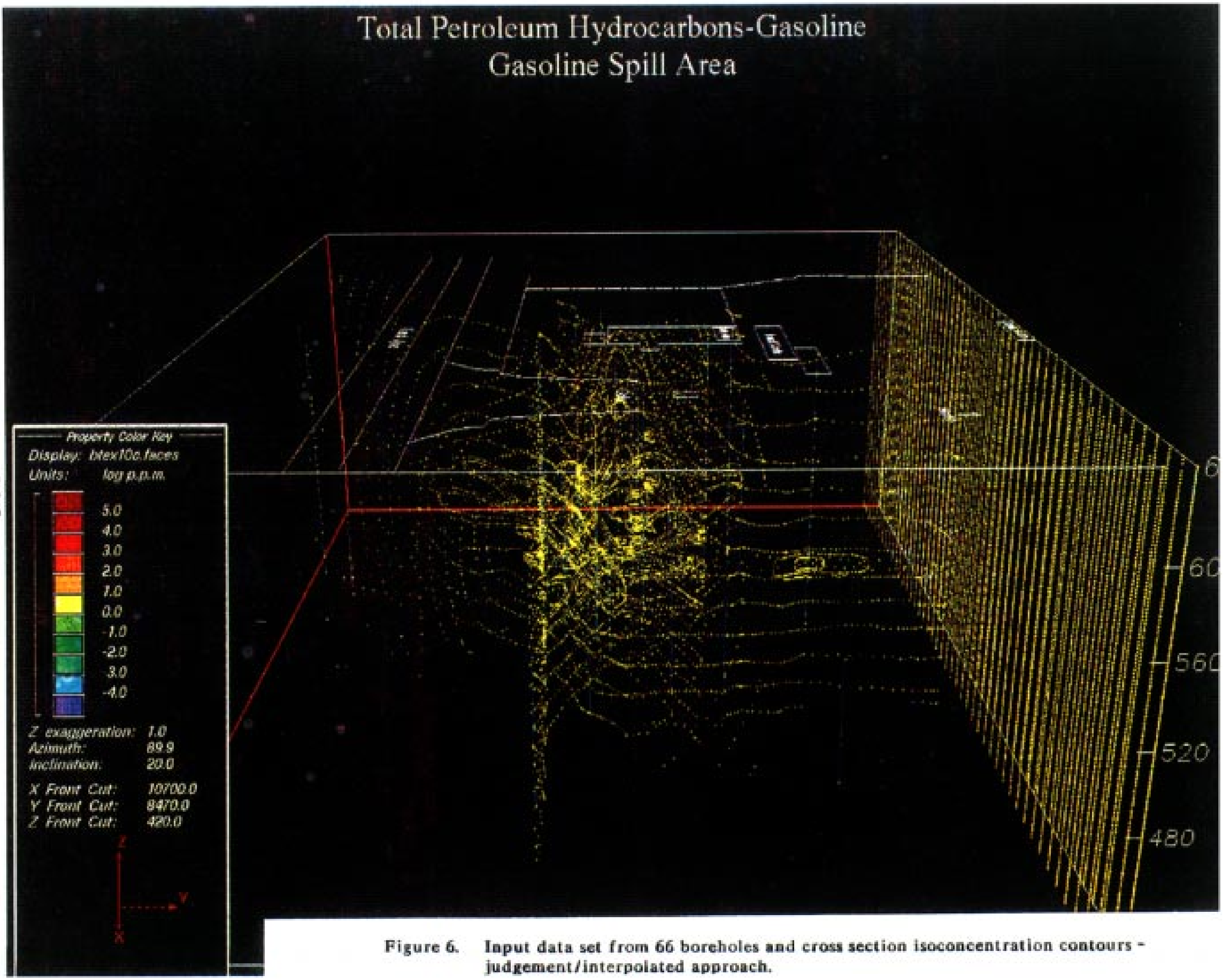


Figure 6. Input data set from 66 boreholes and cross section isoconcentration contours - judgement/interpolated approach.

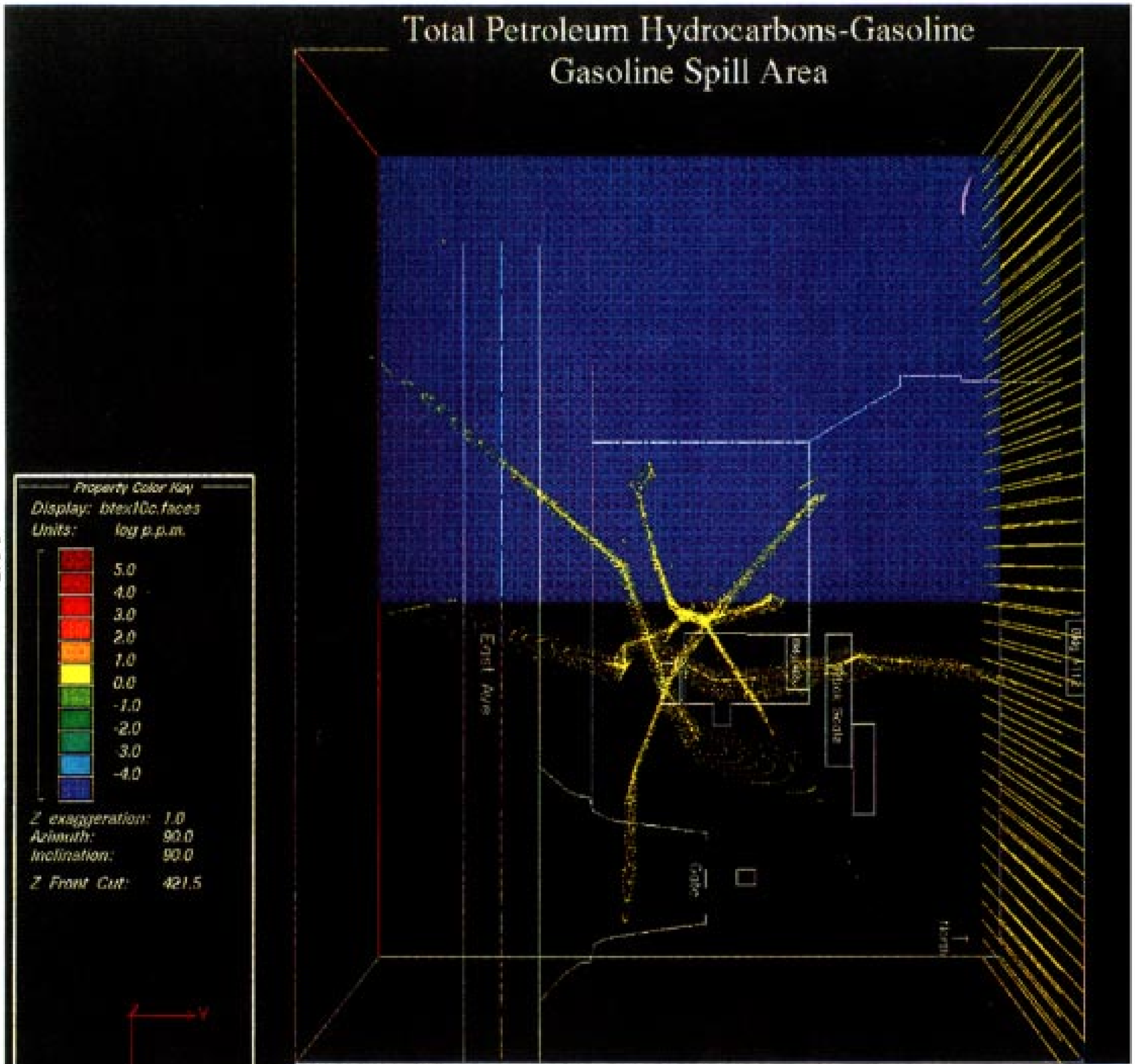


Figure 7. Vertical view of judgement/interpolated approach data set.

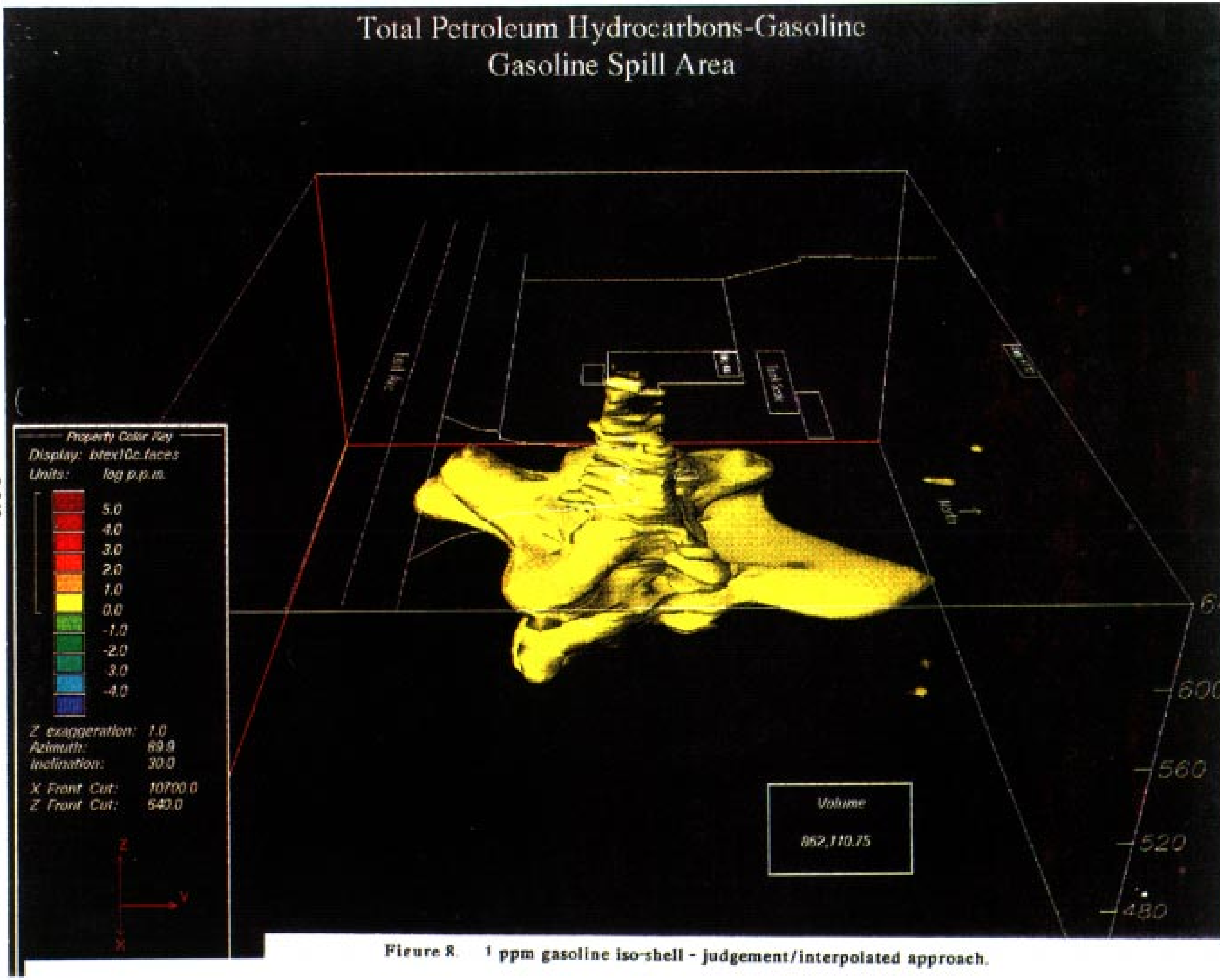


Figure 8. 1 ppm gasoline iso-shell - judgement/interpolated approach.

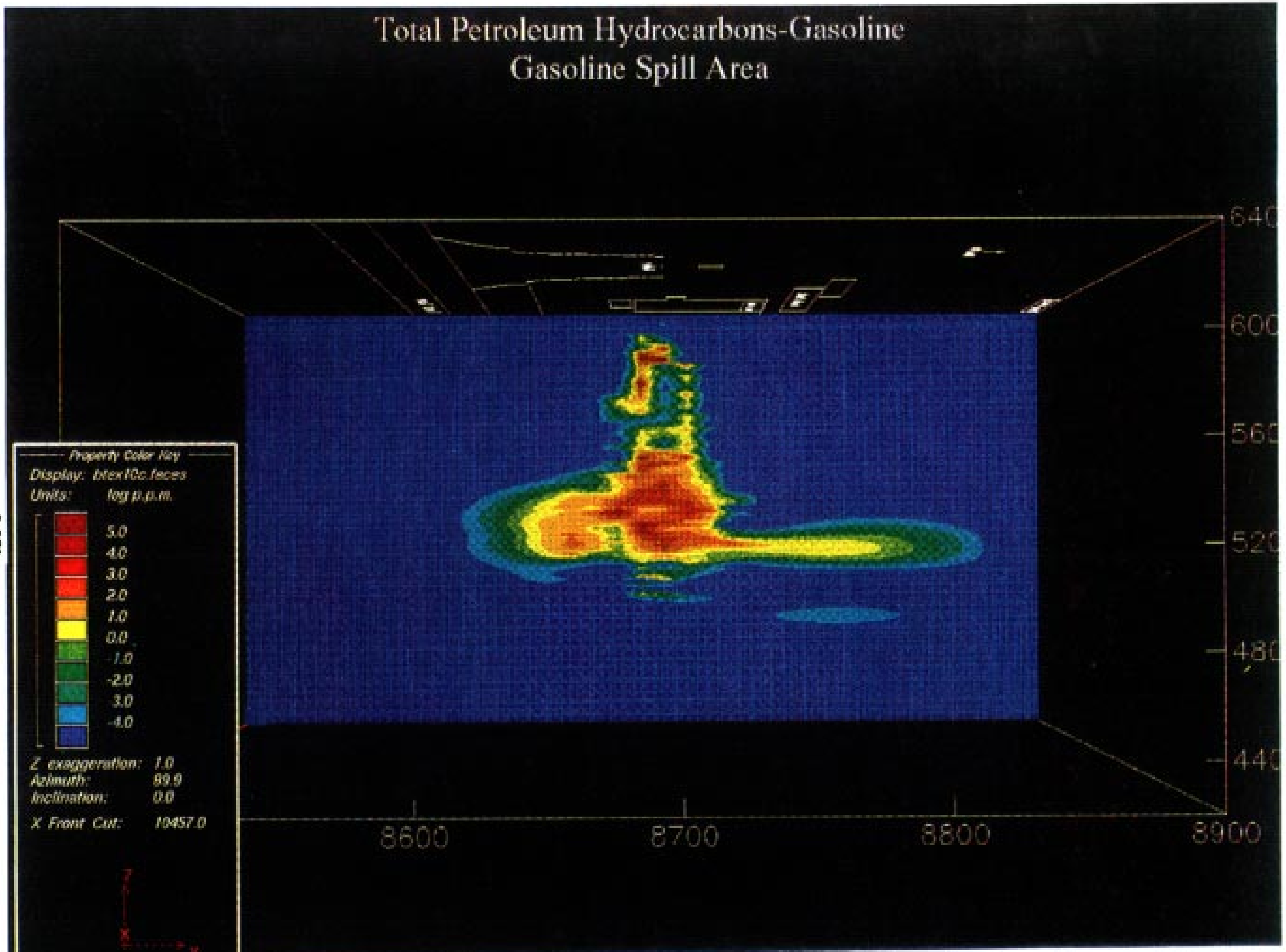


Figure 9. North-south cross section through the GSW-16 area showing gasoline concentrations - judgement/interpolated approach.

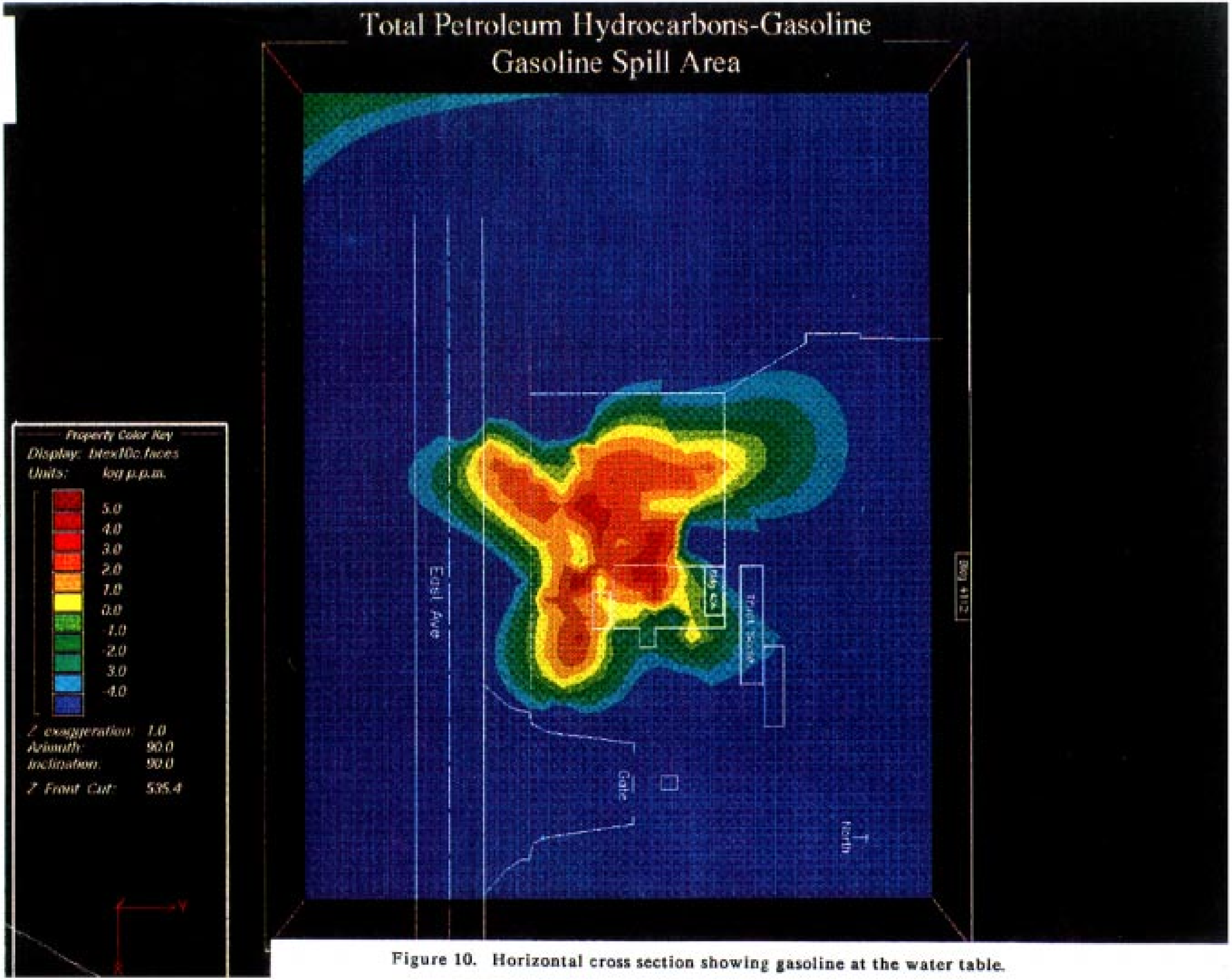


Figure 10. Horizontal cross section showing gasoline at the water table.

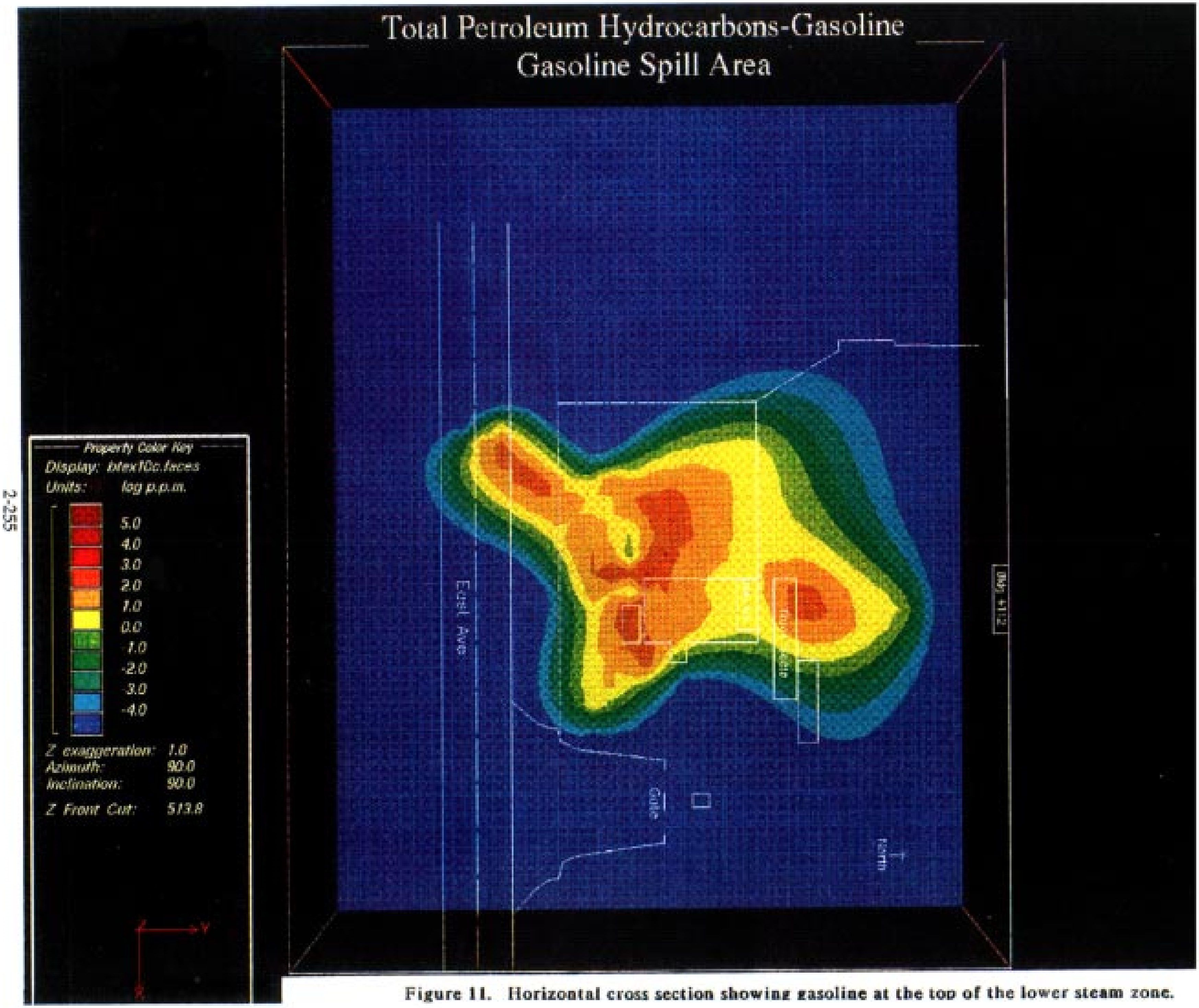


Figure 11. Horizontal cross section showing gasoline at the top of the lower steam zone.

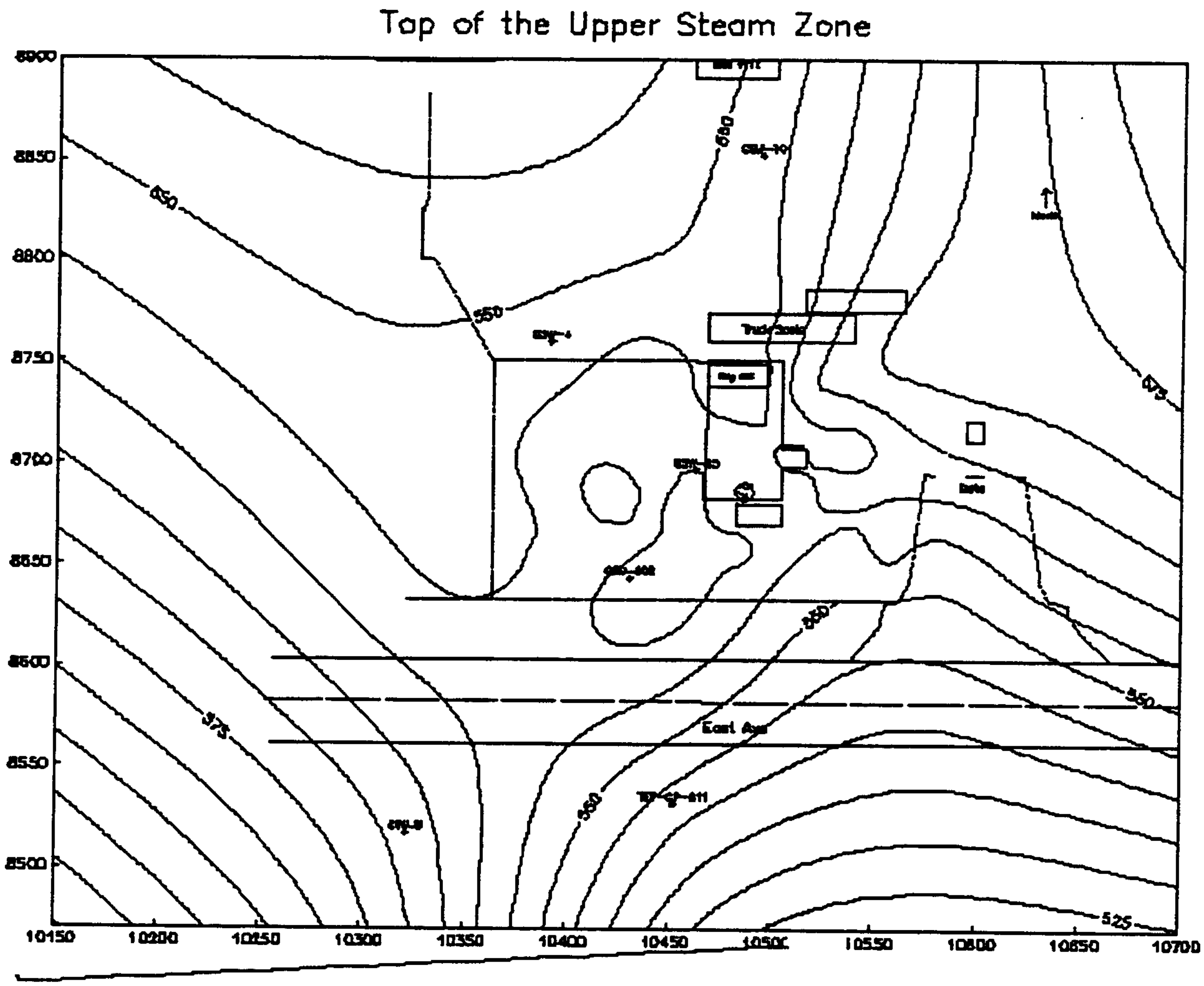


Figure 12. Contour map showing top of the upper steam zone elevations (ft).

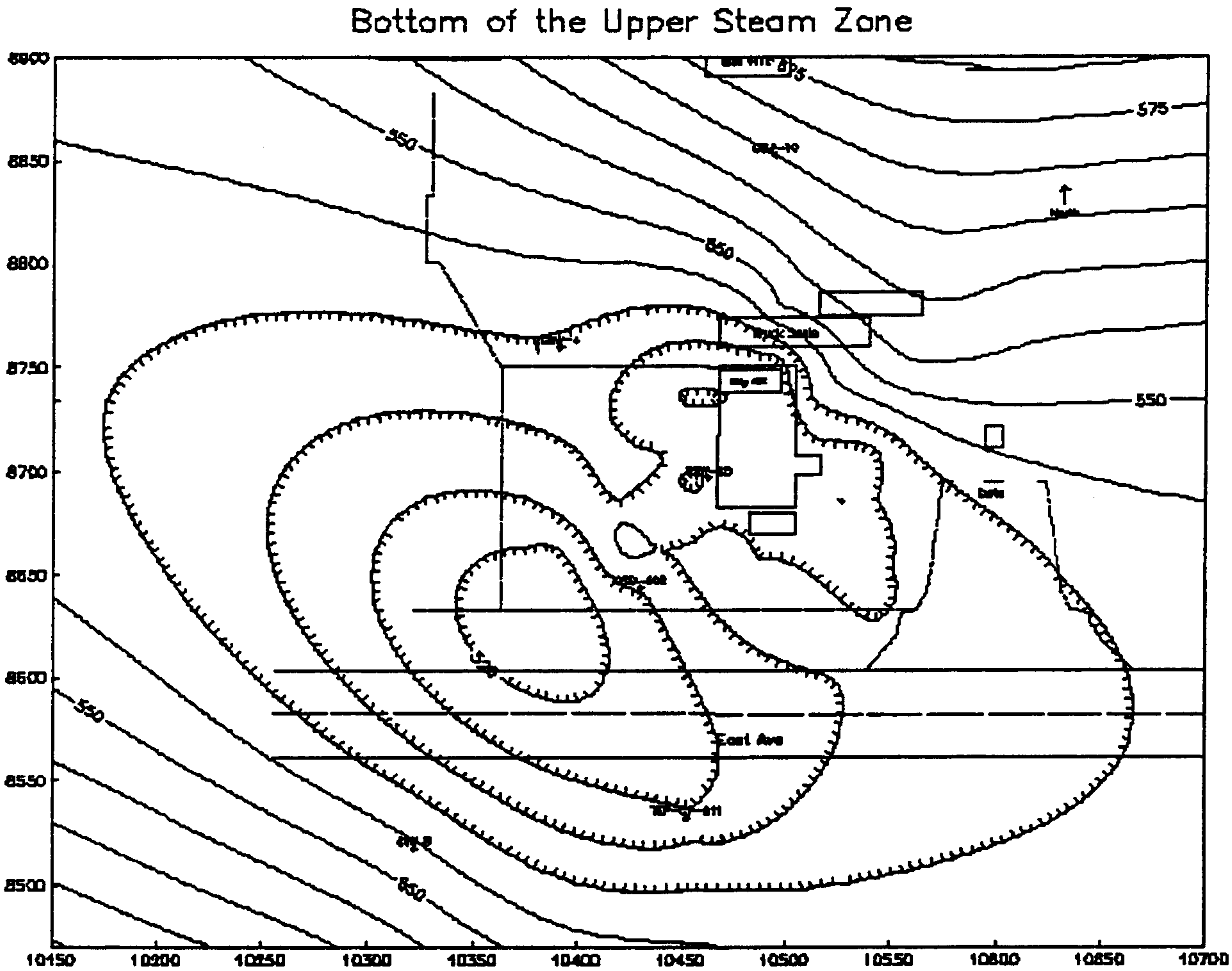


Figure 13. Contour map showing bottom of the upper steam zone elevations (ft).

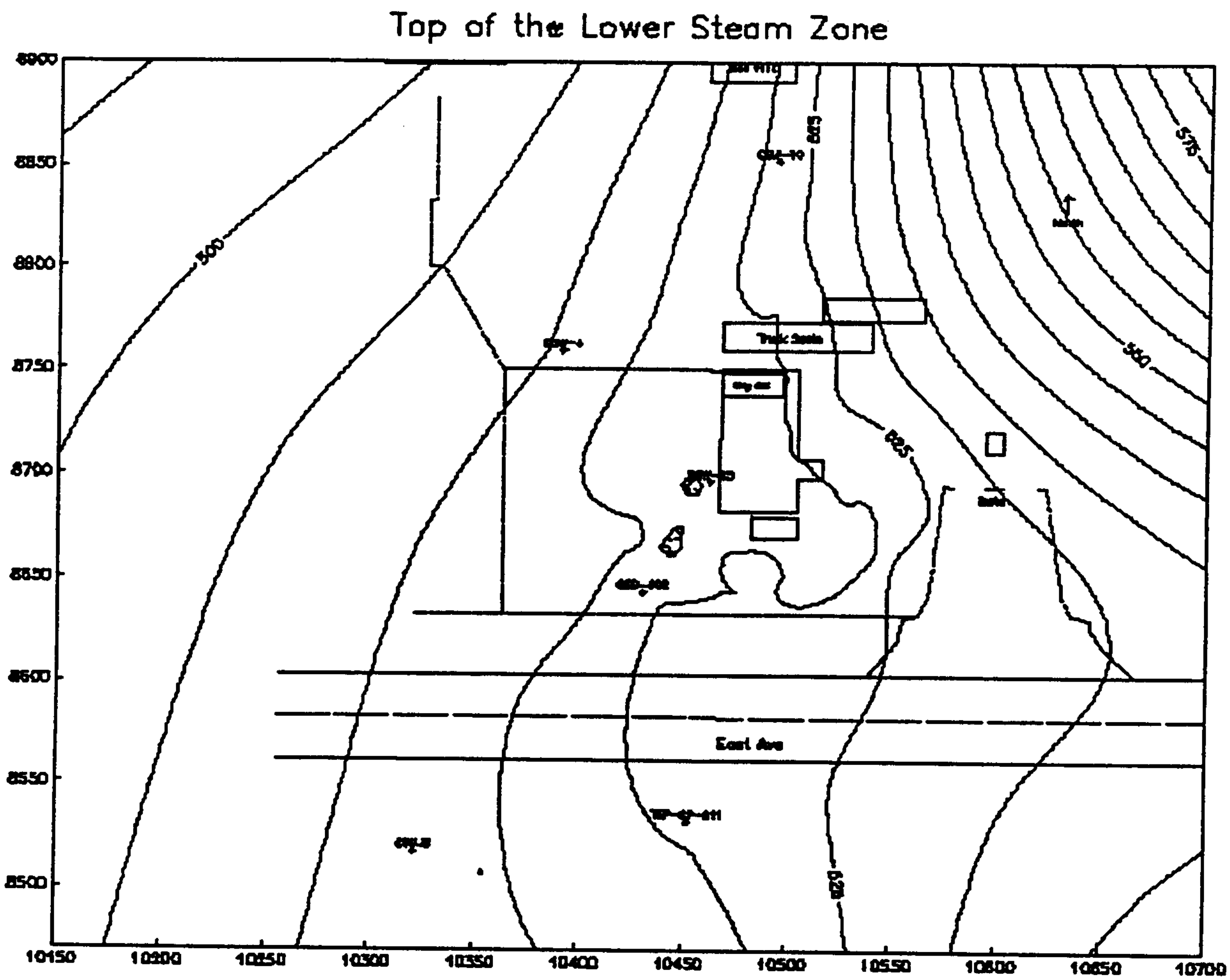


Figure 14. Contour map showing top of the lower steam zone elevations (ft).

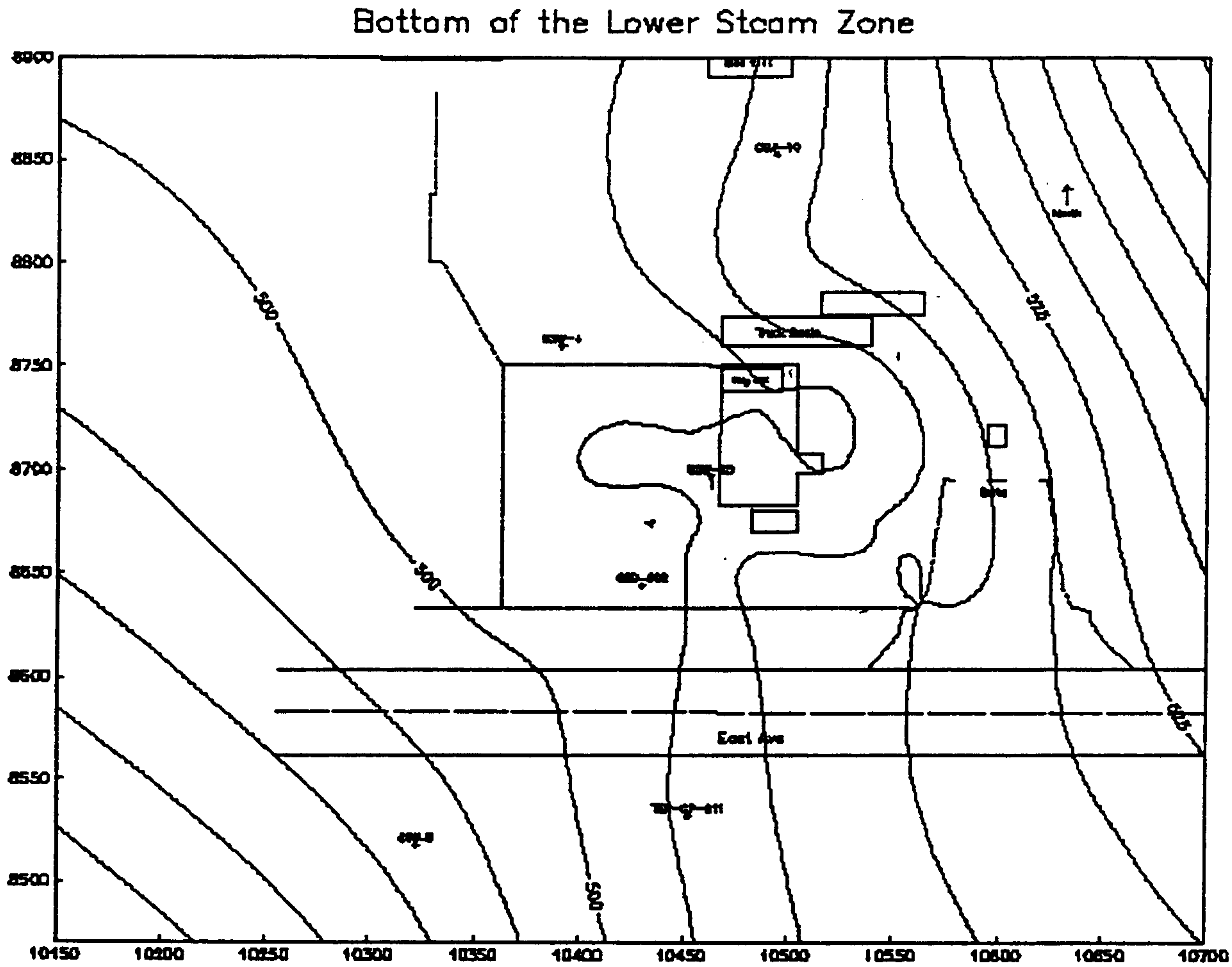


Figure 15. Contour map showing bottom of the lower steam zone elevations (ft).

TABLES

Table 1. Potential indicator compounds for predicting total fuel using GSA-specific sediment sample data.

Benzene to Total Gasoline Ratio	Toluene to Total Gasoline Ratio	Xylene to Total Gasoline Ratio
0.5500	8.7500	10.6250
1.5686	11.3725	9.2157
1.2963	7.7778	9.2593
1.1000	7.5000	9.5000
2.2143	9.2857	10.7143
2.8723	11.7021	11.7021
2.9333	9.2000	10.9333
1.4286	6.8571	17.1429
5.2083	5.2083	3.5417
1.7111	14.0000	18.6667
1.3000	4.9000	9.4000
2.1471	6.1765	9.4118
2.0909	5.9091	8.4545
0.0052	3.3333	2.9167
0.1120	3.7333	3.2000
0.2108	5.1351	0.7568
0.5682	13.1818	10.4545
0.1471	2.5294	8.2353
0.2286	4.5714	9.0000
0.4483	4.8276	7.9310
0.1049	5.3086	7.4074
0.2000	8.6667	8.1667
0.4483	4.1379	7.9310
1.9697	3.9394	7.5758
1.4474	5.0000	3.1579
0.8571	5.4286	8.5714
1.1935	4.5161	7.7419
1.1818	2.4545	5.2727
2.1154	3.8462	2.3077
1.2432	4.0541	7.0270
2.5000	2.5000	2.5000
0.4071	5.5000	14.2857
2.0690	0.6897	11.7241

Table 1. Potential indicator compounds for predicting total fuel using GSA-specific sediment sample data.

Benzene to Total Gasoline Ratio	Toluene to Total Gasoline Ratio	Xylene to Total Gasoline Ratio	
2.0290	5.2174	4.7826	
1.0333	0.5333	9.5556	
0.2162	0.1351	4.5946	
0.0556	0.5333	3.7778	
2.0000	0.7059	3.2353	
0.8455	6.5455	10.9091	
1.3889	7.2222	11.1111	
1.3333	6.0000	9.1667	
0.7500	4.1667	7.0833	
7.5000	1.5625	1.5625	
1.2817	0.7042	9.7183	
1.1667	0.7250	10.0000	
2.5843	0.7865	2.0225	
1.5532	0.7447	2.1277	
1.2549	0.8235	3.1373	
1.5500	0.6000	2.2500	
1.0952	4.7619	8.0952	
1.0625	5.0000	5.6250	
1.42	4.88	7.52	Mean
1.63	11.28	15.20	Variance
1.28	3.36	3.90	Standard D
0.01	0.14	0.76	Min
7.50	14.00	18.67	Max

Table 2 has been intentionally omitted because of its lengthiness.

Those desiring information may contact the author.

Table 3. Estimated total gasoline mass and volume at the GSA - interpolated method.

DRAFT 1.0
Preliminary Mass and Volume Estimate for Total Gasoline - LLNL Gasoline Spill Area.

Concentration Shell (mg/kg)			Shell Volume (Cu.Yds)	Shell Volume (Ft*3)	Data Range		Concentration Geometric Mean	Total Fuel Mass (Kg) **	Total Fuel Volume (Gals)
BTEX 3m (Grid Size=28,32,30 ; Z influence=1.0)									
Vadose Zone									
0.00001	0.00010	Shell 1	81,186	2192031.25	0.00020	0.00020	0.00003	0.0038	0.00
0.00010	0.00100	Shell 2	38,965	1052051.88	0.00020	0.00100	0.00032	0.0181	0.01
0.00100	0.01000	Shell 3	18,571	501416.25	0.00100	0.01000	0.00316	0.0865	0.03
0.01000	0.10000	Shell 4	7,816	211037.28	0.01000	0.10000	0.03162	0.3640	0.13
0.10000	1.00000	Shell 5	3,341	90213.29	0.10000	1.00000	0.31623	1.5561	0.55
1.00000	10.00000	Shell 6	2,176	58748.33	1.00000	10.00000	3.16228	10.1334	3.57
10.00000	100.00000	Shell 7	1,251	33786.70	10.00000	100.00000	31.62278	58.2780	20.51
100.00000	1000.00000	Shell 8	1,055	28481.20	100.00000	1000.00000	316.22777	491.2662	172.93
1000.00000	10000.00000	Shell 9	374	10099.01	1000.00000	10000.00000	3162.27766	1741.9567	613.17
0.00001	10000.00000	Sub Total	154,736	4177865.25	0.00001	10000.00000	Sub Total	2303.6627	810.89

09-Jun-92

DRAFT 1.0

Preliminary Mass and Volume Estimate for Total Gasoline - LLNL Gasoline Spill Area.

Concentration Shell (mg/kg)			Shell Volume (Cu.Yds)	Shell Volume (Ft*3)	Data Range		Concentration Geometric Mean	Total Fuel Mass (Kg) **	Total Fuel Volume (Gals)
Saturated Zone									
0.00001	0.00010	Shell 1	15,133	408590.00	0.00020	0.00020	0.00003	0.0007	0.00
0.00010	0.00100	Shell 2	18,844	508779.53	0.00020	0.00100	0.00032	0.0088	0.00
0.00100	0.01000	Shell 3	28,272	763339.31	0.00100	0.01000	0.00316	0.1317	0.05
0.01000	0.10000	Shell 4	22,603	610279.81	0.01000	0.10000	0.03162	1.0527	0.37
0.10000	1.00000	Shell 5	13,558	366069.06	0.10000	1.00000	0.31623	6.3142	2.22
1.00000	10.00000	Shell 6	5,889	159008.81	1.00000	10.00000	3.16228	27.4271	9.65
10.00000	100.00000	Shell 7	3,045	82224.13	10.00000	100.00000	31.62278	141.8267	49.92
100.00000	1000.00000	Shell 8	2,332	62963.88	100.00000	1000.00000	316.22777	1086.0506	382.29
1000.00000	10000.00000	Shell 9	618	16689.19	1000.00000	10000.00000	3162.27766	2878.6829	1013.30
0.00001	10000.00000	Sub Total	110,294	2977943.75	0.00001	10000.00000	Sub Total	4141.4952	1457.81
		Grand Total		7155809.000			Grand Total	6445.1580	

* Volumes estimated using GMP by Dynamic Graphics Incorpotated, Alameda, CA.

** Total Mass calculated assuming a dry bulk density of 120 lbs/ft*3 and 15% water

Table 4. Estimated total gasoline mass and volume at the GSA - judgement/interpolated method.

26-Aug-92

DRAFT 1.0

Preliminary Mass and Volume Estimate for Total Gasoline - LLNL Gasoline Spill Area.

Concentration Shell (mg/kg)		Shell	Shell Volume * (Cu.Yds)	Shell Volume * (Ft*3)	Data Range		Concentration Geometric Mean	Total Fuel Mass (Kg) **	Total Fuel Volume (Gals)
BTEX 10b (Grid Size=44,35,72; Z influence=1.0)									
Unsaturated Zone (above gplev9206.grd)									
0.00001 -	0.00010	Shell 1	121,825.77	3,289,295.70	0.00001 -	0.00010	0.0000	0.0065	0.00
0.00010 -	0.00100	Shell 2	9,103.17	245,785.70	0.00010 -	0.00100	0.0003	0.0049	0.00
0.00100 -	0.01000	Shell 3	4,993.14	134,814.80	0.00100 -	0.01000	0.0032	0.0267	0.01
0.01000 -	0.10000	Shell 4	3,644.24	98,394.50	0.01000 -	0.10000	0.0316	0.1952	0.07
0.10000 -	1.00000	Shell 5	3,123.37	84,331.10	0.10000 -	1.00000	0.3162	1.6728	0.59
1.00000 -	10.00000	Shell 6	3,058.09	82,568.30	1.00000 -	10.00000	3.1623	16.3783	5.77
10.00000 -	100.00000	Shell 7	3,021.95	81,592.70	10.00000 -	100.00000	31.6228	161.8481	56.97
100.00000 -	1000.00000	Shell 8	2,413.28	65,158.60	100.00000 -	1000.00000	316.2278	1,292.4929	454.96
1000.00000 -	10000.00000	Shell 9	1,493.56	40,326.20	1000.00000 -	10000.00000	3,162.2777	7,999.1475	2,815.70
10000.00000 -	100000.00000	Shell 10	136.70	3,691.00	10000.00000 -	15000.00000	12,247.4487	2,835.6073	998.13
		Total	152,813.28	4,125,958.60			Total	12,307.38	4,332.20

26-Aug-92

DRAFT 1.0

Preliminary Mass and Volume Estimate for Total Gasoline - LLNL Gasoline Spill Area.

Concentration Shell (mg/kg)		Shell	Shell Volume * (Cu.Yds)	Shell Volume * (Ft*3)	Data Range		Concentration Geometric Mean	Total Fuel Mass (Kg) **	Total Fuel Volume (Gals)
BTEX 10a (Grid Size=44,35,144; Z influence=1.0)									
Saturated Zone (below gplev9206.grd)									
0.00001 -	0.00010	Shell 1	71,125.15	1,920,379.00	0.00001 -	0.00010	0.0000	0.0040	0.00
0.00010 -	0.00100	Shell 2	18,613.50	502,564.60	0.00010 -	0.00100	0.0003	0.0104	0.00
0.00100 -	0.01000	Shell 3	12,537.67	338,517.00	0.00100 -	0.01000	0.0032	0.0701	0.02
0.01000 -	0.10000	Shell 4	10,276.04	277,453.00	0.01000 -	0.10000	0.0316	0.5743	0.20
0.10000 -	1.00000	Shell 5	9,656.43	260,723.50	0.10000 -	1.00000	0.3162	5.3966	1.90
1.00000 -	10.00000	Shell 6	10,097.97	272,645.30	1.00000 -	10.00000	3.1623	56.4336	19.86
10.00000 -	100.00000	Shell 7	7,534.39	203,428.60	10.00000 -	100.00000	31.6228	421.0676	148.22
100.00000 -	1000.00000	Shell 8	4,345.31	117,323.30	100.00000 -	1000.00000	316.2278	2,428.4216	854.80
1000.00000 -	10000.00000	Shell 9	838.05	22,627.40	1000.00000 -	10000.00000	3,162.2777	4,683.5425	1,648.61
10000.00000 -	100000.00000	Shell 10	50.39	1,360.66	10000.00000 -	15000.00000	12,247.4487	1,090.7747	383.95
		Total	145,074.90	3,917,022.36			Total	8,686.30	3,057.58
		Grand Total	297,888.18	8,042,980.96			Grand Total	20,993.68	7,389.77

* Volumes estimated using GMP by Dynamic Graphics Incorpotated, Alameda, CA.

** Total fuel mass calculated assuming a dry bulk density of 120 lbs/ft*3 (1.9 gms/cc) and 15% water by wt. in the unsaturated zone, and 20% water by wt. in the saturated zone.

Attachment 1

DUSDP Volumes by Zone - Supporting Calculations

25-Mar-93

DRAFT 1.0

S. Addison and R. Devany

Preliminary Mass and Volume Estimate for Total Gasoline - LLNL Gasoline Spill Area.

Concentration Shell (mg/kg)			Shell Volume (Cu.Yds)	Shell Volume (Ft*3)	Data Range		Concentration Geometric Mean	Total Fuel Mass (Kg) **	Total Fuel Volume (Gals)
BTEX 10b (Grid Size=44,35,72; Z influence=1.0)									
Top of the Upper Steam Zone to the Water Table (between tpupstzn2.grd and gplev9206.grd)									
0.00001 -	0.00010	Shell 1	1,248.78	33,717.00	0.00001 -	0.00010	0.0000	0.0001	0.00
0.00010 -	0.00100	Shell 2	898.08	24,248.25	0.00010 -	0.00100	0.0003	0.0005	0.00
0.00100 -	0.01000	Shell 3	1,027.46	27,741.53	0.00100 -	0.01000	0.0032	0.0055	0.00
0.01000 -	0.10000	Shell 4	1,072.81	28,965.90	0.01000 -	0.10000	0.0316	0.0575	0.02
0.10000 -	1.00000	Shell 5	1,118.00	30,186.05	0.10000 -	1.00000	0.3162	0.5988	0.21
1.00000 -	10.00000	Shell 6	1,343.52	36,274.94	1.00000 -	10.00000	3.1623	7.1955	2.53
10.00000 -	100.00000	Shell 7	1,521.14	41,070.75	10.00000 -	100.00000	31.6228	81.4684	28.68
100.00000 -	1000.00000	Shell 8	1,394.21	37,643.61	100.00000 -	1000.00000	316.2278	746.7027	262.84
1000.00000 -	10000.00000	Shell 9	1,119.45	30,225.02	1000.00000 -	10000.00000	3,162.2777	5,995.4663	2,110.40
10000.00000 -	100000.00000	Shell 10	73.04	1,972.03	10000.00000 -	15000.00000	12,247.4487	1,515.0134	533.28
		Total	10,816.49	292,045.10			Total	8,346.51	2,937.97

25-Mar-93

DRAFT 1.0

S. Addison and R. Devany

Preliminary Mass and Volume Estimate for Total Gasoline - LLNL Gasoline Spill Area.

Concentration Shell (mg/kg)				Shell Volume (Cu.Yds)	Shell Volume (Ft*3)	Data Range			Concentration Geometric Mean	Total Fuel Mass (Kg) **	Total Fuel Volume (Gals)
BTEX 10a (Grid Size=44,35,144; Z influence=1.0)											
Water Table to the Bottom of the Lower Steam Zone (between gplev9206.grd and btmlwstzn2)											
0.00001	-	0.00010	Shell 1	66.39	1,792.54	0.00020	-	0.00020	0.0000	0.0000	0.00
0.00010	-	0.00100	Shell 2	218.33	5,894.90	0.00020	-	0.00100	0.0003	0.0001	0.00
0.00100	-	0.01000	Shell 3	483.10	13,043.70	0.00100	-	0.01000	0.0032	0.0027	0.00
0.01000	-	0.10000	Shell 4	839.86	22,676.30	0.01000	-	0.10000	0.0316	0.0469	0.02
0.10000	-	1.00000	Shell 5	1,695.23	45,771.21	0.10000	-	1.00000	0.3162	0.9474	0.33
1.00000	-	10.00000	Shell 6	2,928.72	79,075.55	1.00000	-	10.00000	3.1623	16.3675	5.76
10.00000	-	100.00000	Shell 7	3,979.23	107,439.10	10.00000	-	100.00000	31.6228	222.3833	78.28
100.00000	-	1000.00000	Shell 8	3,318.53	89,600.20	100.00000	-	1000.00000	316.2278	1,854.5936	652.82
1000.00000	-	10000.00000	Shell 9	782.40	21,124.86	1000.00000	-	10000.00000	3,162.2777	4,372.5376	1,539.13
10000.00000	-	100000.00000	Shell 10	50.16	1,354.30	10000.00000	-	15000.00000	12,247.4487	1,085.6726	382.16
			Total	14,361.95	387,772.64				Total	7,552.55	2,658.50

2-271

25-Mar-93

DRAFT 1.0

S. Addison and R. Devany

Preliminary Mass and Volume Estimate for Total Gasoline - LLNL Gasoline Spill Area.

Concentration Shell (mg/kg)				Shell Volume (Cu.Yds)	Shell Volume (Ft*3)	Data Range			Concentration Geometric Mean	Total Fuel Mass (Kg) **	Total Fuel Volume (Gals)
BTEX 10a (Grid Size=44,35,144; Z influence=1.0)											
Water Table to the Bottom of the Upper Steam Zone (between gplev9206.grd and btmupstzn2)											
0.00001	-	0.00010	Shell 1	3.68	99.28	0.00020	-	0.00020	0.0000	0.0000	0.00
0.00010	-	0.00100	Shell 2	10.05	271.33	0.00020	-	0.00100	0.0003	0.0000	0.00
0.00100	-	0.01000	Shell 3	33.53	905.43	0.00100	-	0.01000	0.0032	0.0002	0.00
0.01000	-	0.10000	Shell 4	79.10	2,135.75	0.01000	-	0.10000	0.0316	0.0044	0.00
0.10000	-	1.00000	Shell 5	117.90	3,183.42	0.10000	-	1.00000	0.3162	0.0659	0.02
1.00000	-	10.00000	Shell 6	182.72	4,933.37	1.00000	-	10.00000	3.1623	1.0211	0.36
10.00000	-	100.00000	Shell 7	249.20	6,728.31	10.00000	-	100.00000	31.6228	13.9266	4.90
100.00000	-	1000.00000	Shell 8	283.47	7,653.75	100.00000	-	1000.00000	316.2278	158.4214	55.76
1000.00000	-	10000.00000	Shell 9	68.11	1,839.06	1000.00000	-	10000.00000	3,162.2777	380.6590	133.99
10000.00000	-	100000.00000	Shell 10	2.59	69.93	10000.00000	-	15000.00000	12,247.4487	56.0586	19.73
			Total	1,030.36	27,819.64				Total	610.16	214.78

2-272

25-Mar-93

DRAFT 1.0

S. Addison and R. Devany

Preliminary Mass and Volume Estimate for Total Gasoline - LLNL Gasoline Spill Area.

BTEX 10a (Grid Size=44,35,144; Z influence=1.0)

The Lower Steam Zone (between tplwstzn2.grd and btmlwstzn2)

Concentration Shell (mg/kg)		Shell Volume (Cu.Yds)	Shell Volume (Ft*3)	Data Range	Concentration Geometric Mean	Total Fuel Mass (Kg) **	Total Fuel Volume (Gals)
0.00001 - 0.00010	Shell 1	50.45	1,362.02	0.00020 - 0.00020	0.0000	0.0000	0.00
0.00010 - 0.00100	Shell 2	130.21	3,515.63	0.00020 - 0.00100	0.0003	0.0001	0.00
0.00100 - 0.01000	Shell 3	241.08	6,509.15	0.00100 - 0.01000	0.0032	0.0013	0.00
0.01000 - 0.10000	Shell 4	429.68	11,601.45	0.01000 - 0.10000	0.0316	0.0240	0.01
0.10000 - 1.00000	Shell 5	937.25	25,305.68	0.10000 - 1.00000	0.3162	0.5238	0.18
1.00000 - 10.00000	Shell 6	1,570.05	42,391.46	1.00000 - 10.00000	3.1623	8.7744	3.09
10.00000 - 100.00000	Shell 7	1,593.29	43,018.89	10.00000 - 100.00000	31.6228	89.0429	31.34
100.00000 - 1000.00000	Shell 8	1,048.61	28,312.35	100.00000 - 1000.00000	316.2278	586.0244	206.28
1000.00000 - 10000.00000	Shell 9	100.36	2,709.69	1000.00000 - 10000.00000	3,162.2777	560.8660	197.42
10000.00000 - 100000.00000	Shell 10	5.50	148.49	10000.00000 - 15000.00000	12,247.4487	119.0358	41.90
	Total	6,106.47	164,874.80		Total	1,364.29	480.23

* Volumes estimated using GMP by Dynamic Graphics Incorpotated, Alameda, CA.

** Total Mass calculated assuming a dry bulk density of 120 lbs/ft*3 and 15% water in the unsaturated zone, and a bulk density of 137 lbs/ft*3 and 100% water in the saturated zone.

25-Mar-93

DRAFT 1.0

S. Addison and R. Devany

Preliminary Mass and Volume Estimate for Total Gasoline - LLNL Gasoline Spill Area.

Concentration Shell (mg/kg)				Shell Volume (Cu.Yds)	Shell Volume (Ft*3)	Data Range			Concentration Geometric Mean	Total Fuel Mass (Kg) **	Total Fuel Volume (Gals)
BTEX 10b (Grid Size=44,35,72; Z influence=1.0)											
Volume within the Steam Injection Ring (steam.ply)											
From 620ft to 590ft											
0.00001	-	0.00010	Shell 1	945.98	25,541.37	0.00001	-	0.00010	0.0000	0.0001	0.00
0.00010	-	0.00100	Shell 2	383.17	10,345.54	0.00010	-	0.00100	0.0003	0.0002	0.00
0.00100	-	0.01000	Shell 3	282.70	7,632.83	0.00100	-	0.01000	0.0032	0.0015	0.00
0.01000	-	0.10000	Shell 4	221.00	5,966.96	0.01000	-	0.10000	0.0316	0.0118	0.00
0.10000	-	1.00000	Shell 5	195.68	5,283.23	0.10000	-	1.00000	0.3162	0.1048	0.04
1.00000	-	10.00000	Shell 6	156.03	4,212.86	1.00000	-	10.00000	3.1623	0.8357	0.29
10.00000	-	100.00000	Shell 7	114.42	3,089.35	10.00000	-	100.00000	31.6228	6.1281	2.16
100.00000	-	1000.00000	Shell 8	93.85	2,534.06	100.00000	-	1000.00000	316.2278	50.2659	17.69
1000.00000	-	10000.00000	Shell 9	57.89	1,563.11	1000.00000	-	10000.00000	3,162.2777	310.0605	109.14
10000.00000	-	100000.00000	Shell 10	24.92	672.76	10000.00000	-	15000.00000	12,247.4487	516.8437	181.93
			Total	2,475.63	66,842.07				Total	884.25	311.26

25-Mar-93

DRAFT 1.0

S. Addison and R. Devany

Preliminary Mass and Volume Estimate for Total Gasoline - LLNL Gasoline Spill Area.

Concentration Shell (mg/kg)			Shell Volume (Cu.Yds)	Shell Volume (Ft*3)	Data Range		Concentration Geometric Mean	Total Fuel Mass (Kg) **	Total Fuel Volume (Gals)
BTEX 10b (Grid Size=44,35,72; Z Influence=1.0) Volume within the Steam Injection Ring (steam.ply) From 590ft to the Top of the Upper Steam Zone (tpupstzn2.grd)									
0.00001 -	0.00010	Shell 1	3,027.49	81,742.25	0.00020 -	0.00020	0.0000	0.0002	0.00
0.00010 -	0.00100	Shell 2	995.99	26,891.75	0.00020 -	0.00100	0.0003	0.0005	0.00
0.00100 -	0.01000	Shell 3	716.72	19,351.46	0.00100 -	0.01000	0.0032	0.0038	0.00
0.01000 -	0.10000	Shell 4	607.68	16,407.23	0.01000 -	0.10000	0.0316	0.0325	0.01
0.10000 -	1.00000	Shell 5	571.75	15,437.19	0.10000 -	1.00000	0.3162	0.3062	0.11
1.00000 -	10.00000	Shell 6	615.41	16,616.13	1.00000 -	10.00000	3.1623	3.2960	1.16
10.00000 -	100.00000	Shell 7	664.97	17,954.20	10.00000 -	100.00000	31.6228	35.6141	12.54
100.00000 -	1000.00000	Shell 8	342.34	9,243.09	100.00000 -	1000.00000	316.2278	183.3469	64.54
1000.00000 -	10000.00000	Shell 9	117.63	3,175.88	1000.00000 -	10000.00000	3,162.2777	629.9705	221.75
10000.00000 -	100000.00000	Shell 10	46.90	1,266.28	10000.00000 -	15000.00000	12,247.4487	972.8173	342.43
		Total	7,706.87	208,085.47			Total	1,825.39	642.54

Appendix R

Hydraulic Testing at the Gasoline Spill

by
Janet Macdonald
Zafer Demir
Eric Nichols
Charlie Noyes

May 3, 1993

Hydraulic Testing at the Gasoline Spill Area

INTRODUCTION

Seven one-hour injection tests and one seven-hour extraction test were conducted between August 6 and 15, 1992 to further characterize the subsurface hydraulic properties and predict steam migration pathways in the Gasoline Spill Area, as part of the Dynamic Stripping Demonstration Project (DSDP). Dynamic stripping is a combination of steam injection and vacuum extraction with direct electrical resistance heating of subsurface materials. Steam will be injected into two primary aquifers. Previous investigations and lithologic logging indicate that the upper aquifer, named the Upper Steam Zone (USZ), is only partially saturated. The lower aquifer, named the Lower Steam Zone (LSZ), is fully saturated and has a higher permeability. Electrical resistance heating will be performed on the low-permeability silt and clay sediments. These tests are part of the overall characterization being conducted at the Gasoline Spill Area by the Lawrence Livermore National Laboratory (LLNL) in support of the dynamic stripping process demonstration. This memorandum describes the objectives of the hydraulic tests, the procedures and results. In addition, the hydraulic test results are compared with the area's inferred stratigraphy and with results obtained from a simultaneous tiltmeter survey to validate its use in future hydraulic tests. Finally, conclusions and recommendations for future work are discussed.

The DSDP well field consists of six 4-in injection wells in a ring pattern surrounding two 8-in extraction wells. In addition, the area contains 11 temperature monitoring wells, and over 17 monitor wells (Fig. 1). Each injection well consists of two separate casings screened across the USZ and the LSZ, respectively. The extraction wells are screened continuously from depths of 50 to 140 ft, corresponding to the top of the USZ and the bottom of the LSZ, respectively. The temperature wells, which will be used to monitor the position of the steam front, are completed as a one-inch piezometer screened with KYNAR®, a flexible, heat resistant plastic, within a 2-in fiberglass casing. Some problems were encountered during the installation of these wells, so the validity of water level measurements from these wells is unknown. All but one of the injection tests were conducted in the LSZ, which is more transmissive than the USZ.

During the injection and extraction tests, Hunter Geophysics conducted a preliminary survey to measure subsurface pressure propagation characteristics using an array of 17 shallow tiltmeters surrounding the Gasoline Spill Area. The tiltmeters will be used during the dynamic stripping operation to infer steam migration pathways. The objectives of hydraulic testing at the Gasoline Spill Area were to:

1) Determine LSZ aquifer parameters by using one or more analytic methods (e.g., Cooper-Jacob, Theis, Theis recovery), depending on character of the data,
2) Determine the existence and degree of communication between the pumping well and nearby observation wells, including the six steam injection wells,
3) Confirm the apparent lack of hydraulic communication between the upper and lower steam zones,
4) Compare the overall hydraulic test response with the inferred stratigraphy,
5) Compare the tiltmeter response with the water level response and assess the utility of tiltmeters in future hydraulic tests,
6) Provide hydrologic data to help predict the response of the specified wells to steam injection and extraction, and the primary direction(s) of steam migration.

Hydraulic Test Procedure

By 6:15 hrs on August 6, the following 15 wells were instrumented with submersible pressure transducers to monitor water levels (Fig. 1): lower-zone steam injection wells GIW-815, GIW-818, GIW-819, and GIW-820; upper-zone steam injection wells GIW-819 and GIW-820; extraction well GEW-816; monitoring wells GSW-1A, GSW-6, GSW-8, GSW-13, GSW-216; and piezometers in temperature/electrical resistance tomography imaging wells TEP-SNL-001 (located on Sandia National Laboratory property), TEP-GP-004, and TEP-GP-005. The two remaining steam injection wells south of the LLNL fence, GIW-813 and GIW-814, were not equipped with transducers for the first day of tests due to "protesting" activities in this area.

Background water levels were recorded by data loggers for four hours prior to the first injection test. For most tests, the data loggers were programmed to record water level readings every second for the first 20 seconds, every 2 seconds for the next 30 seconds, every 5 seconds for the next minute, every 10 seconds for another minute, every 30 seconds for the next 7 minutes, and every 1 minute thereafter. For the observation wells located at the perimeter of the study area, the data loggers were programmed to record water levels every five minutes.

Extraction Test

Extraction well GEW-816 has an 8-in diameter casing, is screened continuously from 50 to 140 ft, and was equipped with a Grundfos 6-10 submersible pump for the extraction test. Extraction began on August 15 at 10:20 hrs and continued until 17:20 hrs at a rate of about 39 gpm. For this long-term pumping test, the data recording frequency was decreased from every 5 to 15 minutes after several hours of pumping. An electronic flow sensor measured and recorded pumping rates during the test. The discharge rates were verified using a calibrated vessel and stopwatch. During the test, water levels in the instrumented wells and piezometers were periodically verified by hand using an electric water level meter. Water levels in uninstrumented wells GSW-1A, GSW-3, GSW-4, GSW-10, GEW-808, and TEP-GP-010 (Fig. 1) were monitored by hand each day prior to the test, every hour during the test, and two times following the end of the test. All discharged water was conveyed to above-ground temporary storage tanks prior to treatment and disposal.

After pumping was stopped, water levels in all the instrumented wells were monitored for an additional 40 hrs.

Injection Tests

Individual one-hour constant-head injection tests were performed on the six steam injection wells screened in the lower zone and one steam injection well screened in the upper zone. Initially, four tests were conducted in two days at two tests per day. However, the extensive vehicle traffic and other activity in the area affected the tiltmeter responses, causing the remaining tests to be conducted outside working hours. The transducers from TEP-SNL-001 and GSW-1A were removed and placed in GIW-813 and GIW-814 after the first day of testing was complete.

Prior to each test, the transducer in the injection well was raised to about 50 feet below the top of the casing so that the water height in the well would not exceed the transducer range of about 50 ft. As a result, the transducers were about 50 ft above the static water table for the initial portion of the test, affecting the continuity of the water level data for the injection well. Water from a nearby fire hydrant was conveyed to the injection well via a fire hose. Initially, a surge of water filled the casing, then the flow rate was decreased to prevent the casing from overflowing. Water levels were sustained near the top of the casing throughout each test at a constant flow rate. The lower steam-zone casing in GIW-819 overflowed during injection, and the excess water flowed into the upper steam-zone casing, exceeding the transducer's range. However, the data from nearby observation wells did not show any effects of this occurrence. Table 1 presents some of the details of each injection test.

RESULTS

The hydraulic test data were analyzed to determine aquifer parameters, such as transmissivity (T), hydraulic conductivity (K), storativity (S), and specific storage (S_s). The method chosen for the analysis depended on the nature of the well response. The extraction test data were analyzed by the Theis, Theis recovery, and Cooper and Jacob methods for comparison. The injection test results were analyzed using the method of Cooper and Jacob (1946), which is an approximation to the Theis (1935) method.

All of the methods used in analyzing the hydraulic tests involve plotting the drawdown, or buildup, of water levels versus time on either semi-log or log-log graphs, with initial time defined as the onset of pumping. Drawdown data plotted in semi-log form typically yield a straight line that can be analyzed by the Cooper and Jacob method. This method is usually more reliable for longer duration tests. A log-log plot of drawdown versus time yields a curve that can be fitted to the Theis type curve. Using values from a matching point, a transmissivity and hydraulic conductivity value can be calculated with the Theis equation. Theis's recovery method is applied to water level recovery data collected following pump shut in. This data is plotted on a semi-log graph with normalized time, and aquifer parameters are calculated using the appropriate equation.

Extraction Test Data Analysis

The extraction test data from GEW-816 and each observation well were plotted on semi-log and log-log graphs to calculate representative transmissivity values. All the semi-log plots of both the drawdown and recovery data for each observation well had two slopes. Representative plots are shown in Figures 2 and 3, respectively. The slope of the data increased after about the third hour of pumping, indicating an increased rate of drawdown. Such a change in slope suggests that the pressure perturbation may have reached a less conductive zone or aquifer boundary at some distance from the pumping well. Transmissivity values were calculated using the Cooper and Jacob method for each slope. The average LSZ transmissivity for the early time and later time data are about 12,000 and 6,200 gpd/ft, respectively. Based on the 11-ft average thickness of the lower aquifer, as interpreted from the well logs and numerous cross sections of the area, the average LSZ hydraulic conductivity values for the early and later time are about 1,100 and 560 gpd/ft^2, respectively.

The drawdown data plotted on log-log graphs matched the Theis curve very closely. However, most of the observation well data also showed a deviation from the Theis type curve after about three hours of pumping in the direction indicating a greater rate of drawdown (Fig. 4). The average transmissivity calculated using the Theis analysis is 8,700 gpd/ft (Table 2).

Water level recovery data is typically of better quality than drawdown data because it is often difficult to achieve a constant discharge during pumping. Therefore, semi-log plots of the recovery data were also prepared for the pumping well and each observation well. A representative semi-log plot of the recovery data, with the characteristic change in slope, is shown in Figure 3. The average transmissivity calculated using Theis recovery analysis is 13,000 gpd/ft. Finally, a distance-drawdown plot was created with the observation drawdowns at the 100 minute time step. The transmissivity and hydraulic conductivity were calculated as 12,000 gpd/ft and 1,100 gpd/ft^2, respectively, closely agreeing with the other results.

Storativity values calculated using the Cooper-Jacob and Theis methods were also in very close agreement, with a representative value of about 3.8×10^{-3}. This value indicates that the LSZ responds as a confined aquifer. The aquifer parameters calculated for each well using these methods are shown in Table 2 for comparison. All in all, the values using the various methods of analysis are remarkably close in range.

A number of pump tests have been previously performed in the Gasoline Spill Area to characterize the subsurface and calculate aquifer parameters. Table 3 presents the aquifer parameters calculated from pump test data for wells screened in both the USZ and LSZ. A summary of all hydraulic test results are presented quarterly in the LLNL Ground Water Project Monthly Progress Reports.

Contour Plot Analysis of Drawdown

The lateral extent of drawdown during the extraction test was analyzed by contouring the water levels in all the observation wells at successive one-hour intervals. The extraction test was used because of the additional hand-measured data and longer duration of the test. Several interpolation algorithms were compared, and the resultant plots yielded a similar shape of the cone of depression. Figures 5 through 7 show the extent and magnitude of the drawdowns at successive times after pumping began. The cone of depression generally maintains its shape during pumping, but drawdowns increase with time. The north-south elongation of the drawdown cone suggests that the LSZ may be thicker or more permeable in this direction. However, the shape of the east side of the cone is governed only by data from temperature well TEP-GP-010, which may not be reliable due to possible poor construction.

Injection Test Data Analysis

For each injection test, an average aquifer transmissivity value was calculated for every observation well. For the Cooper and Jacob analyses, the latter portion of the data was analyzed due to the short test durations to avoid possible well-bore storage effects. Only one definitive slope was observed in all of the data plots, probably due to the short test durations. Average transmissivity values ranged from 9,500 to 20,000 gpd/ft. The corresponding hydraulic conductivities, estimated by dividing the transmissivity values by the average aquifer thickness of 11 ft, were very similar, ranging from 850 to 1,800 gpd/ft^2. Appendix A presents the estimated hydraulic parameters for each injection test in tabular form.

The GIW-813 and GIW-814 lower-zone injection tests had no significant effect on the observation well water levels. These wells could only accept injection rates of 10 and 2 gpm, respectively, as compared with about 20 to 30 gpm for the other injection tests. It is currently unclear whether the low injection rates were due to the well completion, screen clogging, or the formation. Consequently, aquifer property analyses could not be performed for these two injection tests.

Upper zone observation well GIW-814 had no significant response during any of the injection tests. In addition, the temperature/ERT imaging wells, TEP-SNL-001, TEP-GP-004, and TEP-GP-005 (Fig. 1), appeared to respond less than the observation wells, which may be due to poorer well completion or well development.

Correlation of Hydraulic Test Results with Inferred Stratigraphy

The thickness of the higher permeability sediments in the Gasoline Spill Area were contoured to create an isopach (equal thickness) map based on 10 hydrogeologic cross sections constructed for the pre-dynamic stripping hydrogeochemical characterization. The isopach contouring reveals two offset, northwest-trending thick regions, which are interpreted as braided-stream channel deposits. Detailed geologic logging suggests that the deposits should act as preferential flow pathways during dynamic stripping.

The north-northwest elongation of the cone of depression during the extraction test coincides with the locations where the lower aquifer is significantly thicker (Fig. 8), suggesting that the pumping well draws more water from these thicker areas. In addition, based on the contour plots and existing knowledge of the subsurface geology at the Gasoline Spill Area, the aquifer probably pinches out into very low permeability sediments east and west of the Gasoline Spill Area. The sediments about 100 ft east of Building 406 are known to be primarily low-permeability silts and clays.

ANALYSIS OF TILTMETER SURVEY

During the seven injection tests and the extraction test, Hunter Geophysics measured the surface deformation due to the pressure transients using an array of 17 high-gain tiltmeters. Following the first two days of testing, the subsequent tests were conducted after high-traffic hours to reduce noise levels and improve the results.

The tiltmeter measures tilt in the north-south and east-west directions. These data consist of two vectors, whose resultant vector represents the magnitude and direction of the surface deformation gradient. The magnitude of the resulting vector is the tilt caused by deformation. Low-frequency effects, such as lunar and solar earth tides, and daily thermal changes can typically be filtered out. High-frequency effects, such as industrial noise and vehicular traffic noise, can also be filtered if a baseline noise level is established.

The tiltmeter technology is successfully used in the petroleum industry for mapping hydraulically-induced fractures in deep reservoirs. The use of this technology for shallow sources requires adjustments to the equipment and to the data analysis procedure.

The tiltmeter responses to injection tests were much more pronounced than those for the extraction test. The injection tests probably caused a much higher initial pressure pulse in the subsurface with the instantaneous introduction of over 50 ft of pressure head into the aquifer. The resulting vectors from each tiltmeter are shown in conjunction with contour plots of the maximum build-up for a representative injection test and the maximum drawdown for the extraction test in

Figure 9 and 10, respectively. The contour plots were generated by interpolating the maximum water level changes in 12 monitoring well during each test.

The water level data for the injection test well was not available as previously discussed. Therefore, build-up at the injection well was estimated to be twice that observed in the monitoring well showing the maximum build-up. This assumption was essential to create a correctly-centered water level mound, however, it does affect the estimated hydraulic gradients.

The tiltmeter response to the drawdown portion of the extraction test was not suitable for analysis because the tilts were very small. However, the signal obtained following pump shut-in was sharp and more reliable. For this reason the maximum drawdown during the extraction test was compared with the tiltmeter signal obtained during water level recovery. The tiltmeter locations with tiltmeter vector data, and monitoring well locations with maximum build-up and drawdown values are given in Table 4 and 5, respectively.

Correlation of Hydraulic Test Results with the Tiltmeter Survey

The water level and tiltmeter data were compared to determine if tiltmeters were an effective method for monitoring responses to future hydraulic tests. The comparison shows that there is a general qualitative agreement in the direction of induced gradients. Although the tiltmeters have a higher sensitivity to the magnitude of the ground surface deformation, the magnitudes of the tilt vectors do not strongly correlate with the magnitudes of the hydraulic gradients. This may be the result of local stress conditions, preferential pathways for flow, effects of complex stress changes due to lateral deformations, or insufficiently filtered background noise.

The tiltmeter results from these tests are not adequate to infer subsurface characteristics, such as preferential flow pathways, structural features or extent of the pressure transients. The tiltmeter locations may have been too far from the tested wells and observation wells to directly compare the hydraulic data with the tiltmeter responses. The build-up/depression cones contoured for comparison are reliable for a limited area around the test wells, but cannot be accurately interpolated over the larger area enclosed by the tiltmeter network.

CONCLUSIONS

1. The LSZ is relatively interconnected and highly transmissive, because of the consistent

hydraulic conductivity and storativity values obtained among all wells monitored in the Gasoline Spill Area.

2. Some type of aquifer boundary(s) probably exists in the LSZ, as indicated by the change in slope of the drawdown versus time data in the semi-log plots, the deviation of the later-time data from the Theis curve on the log-log plots, and the elongated cone of depression in the north-south direction. It is likely that this "aquifer boundary(s)" is related to the lateral pinching out of the permeable layer to the ease and west.

3. The LSZ injection tests yielded a slightly higher aquifer transmissivity range (9,500 to 20,000 gpd/ft) than the extraction test (9,000 to 12,000 gpd/ft), probably due to the difference in duration of the extraction and injection tests. In the shorter-duration injection tests, the resulting pressure disturbance only affected a smaller region of aquifer around the well screen. The longer-duration extraction test affected a much larger region and probably included the less transmissive sediments that exist at the outer margins of the Gasoline Spill Area. However, although the average transmissivity values calculated from the extraction test are slightly lower, this difference is not considered significant. Representative transmissivity and hydraulic conductivity values of the LSZ are 12,000 gpd/ft and 1,100 gpd/ft^2, respectively.

4. The USZ well monitored during the hydraulic tests did not respond to any of the extraction or injection tests. These observations are consistent with the previous indication that little or no hydraulic communication exists between the upper and lower steam zones (Dresen *et al.*, 1987).

5. Although the extraction well is screened throughout the upper and lower steam zones, only the wells screened in the LSZ responded. The lack of response in the USZ is probably due to the lower zone's higher transmissivity, so most of the ground water was extracted from this zone.

RECOMMENDATIONS

1. Perform short-term hydraulic tests on all of the LSZ injection wells to obtain aquifer parameters at each well location. It was not possible to calculate aquifer parameters at each injection well because the transducers were raised above the water table prior to the test,

so no short-term water level data was obtained.

2. Conduct a simultaneous injection/extraction test to better determine flow paths, the regional response of the aquifer system, and the extent of influence. Such a test would represent the actual steam injection/extraction process and the aquifer response.

3. Perform short-term tests on the USZ. However, this aquifer is only partially saturated, so the aquifer test analysis may be complicated.

References

Cooper, H. H. and C. E. Jacob (1946). A generalized graphical method for evaluating formation constants and summarizing well field history. *Am. Geophys. Union Trans.* Vol. 27, pp. 526-534.

Dresen, M. D., E. M. Nichols, R. O. Devany, W. F. Isherwood, D. S. Thompson, M. W. Small, D. N. Homan (1987), *LLNL Ground Water Project Monthly Progress Report,* Lawrence Livermore National Laboratory, Livermore, Calif. (UCAR-10160-87-8).

Theis, C. V. (1935). The relation between the lowering of the piezometric surface and the rate and duration of discharge of a well using ground water storage. *Trans. Amer. Geophys. Union*, Vol. 16, pp. 519-524.

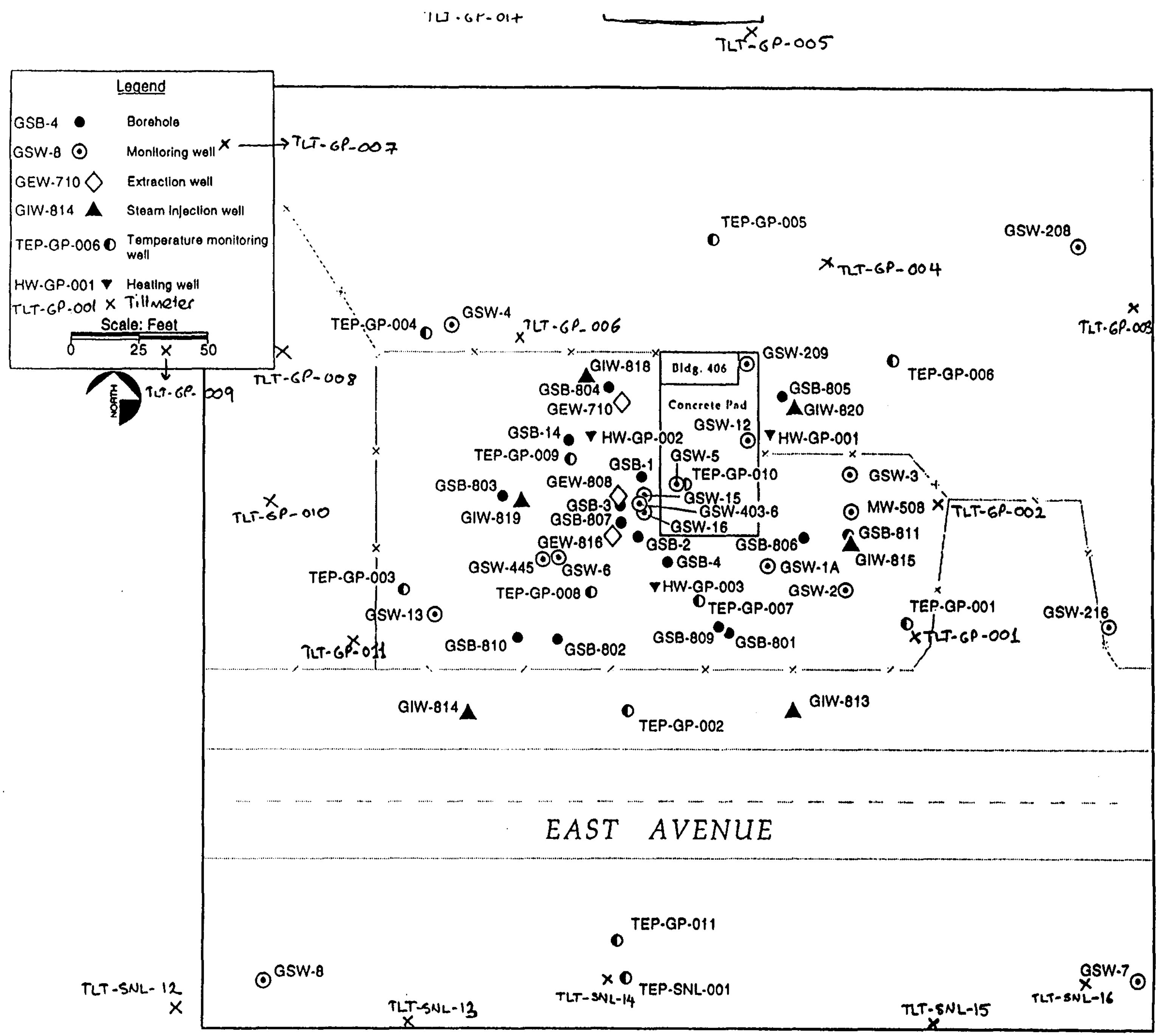
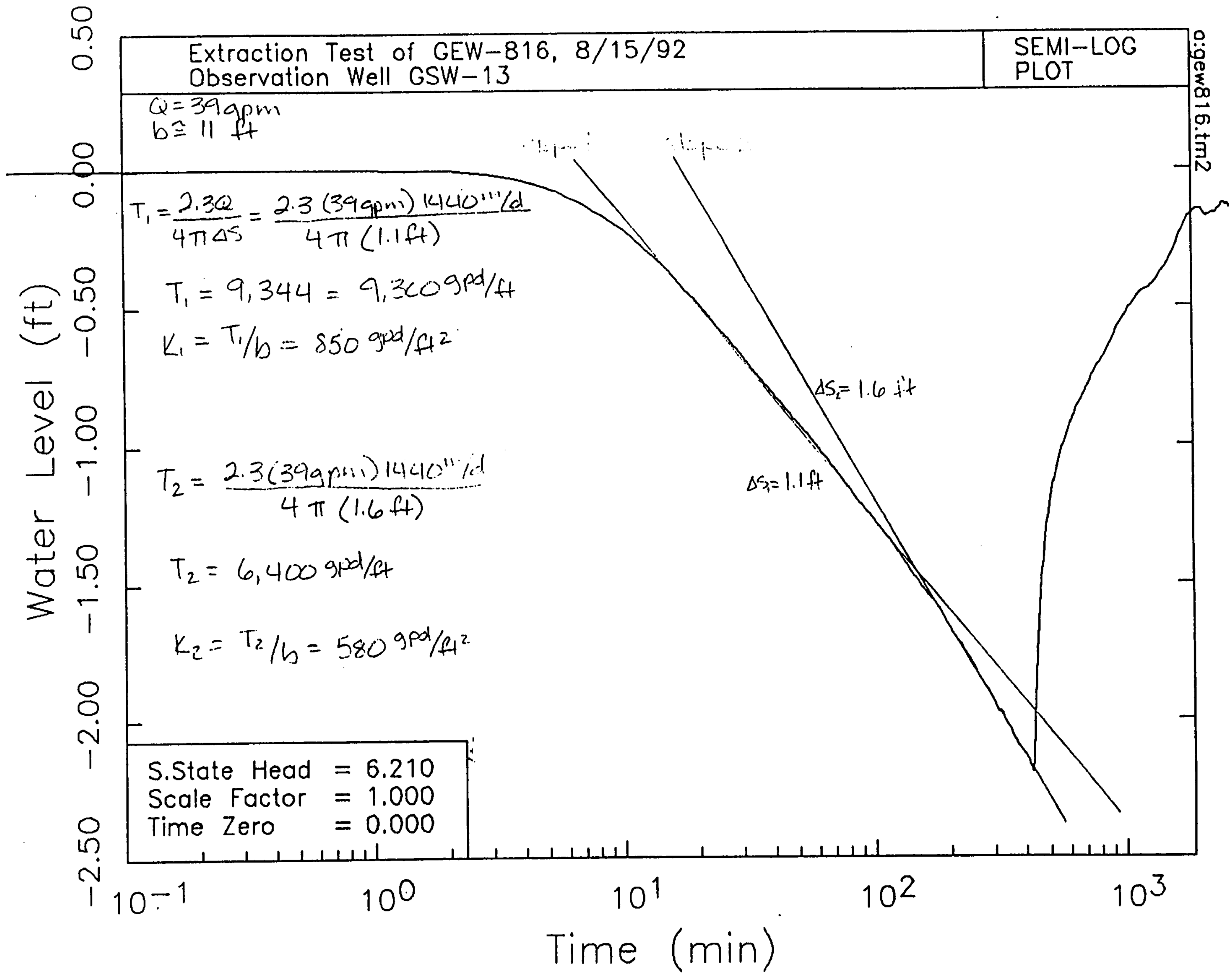


Figure 1. Well and borehole locations at the Gasoline Spill Area, September 1992

LLNL93-014

Weiss Associates

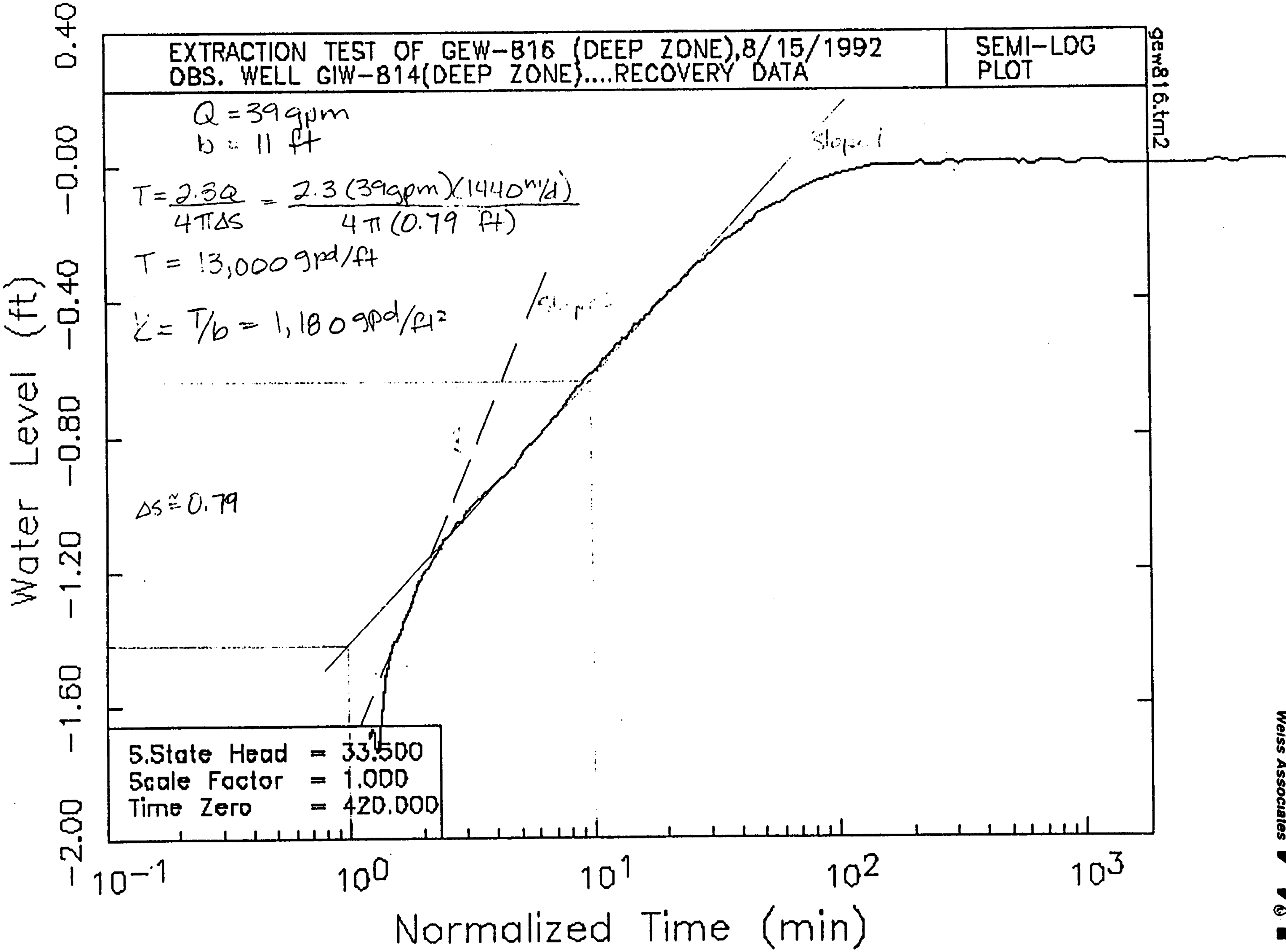
Figure 2. Semi-log plot of observation well GSW-13 drawdown data from the extraction test of GEW-816, showing two slopes to the data.



2-290

Weiss Associates

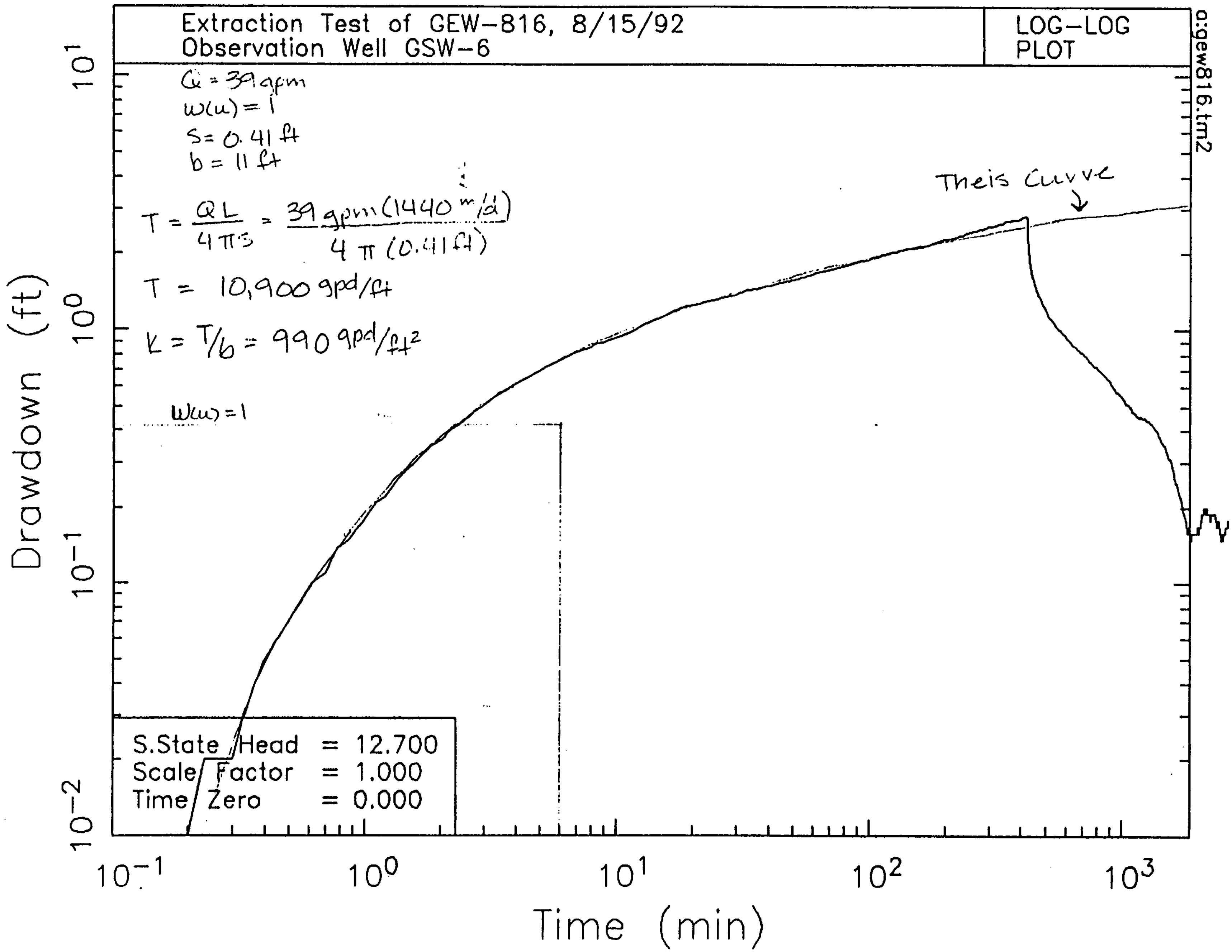
Figure 3. Semi-log plot of observation well GIW-814 recovery data from the extraction test of GEW-816.



2-291

Weiss Associates

Figure 4. Log-log plot of observation well GSW-6 drawdown versus time for the extraction test of GEW-816, showing the data's deviation from the Theis curve at later times.



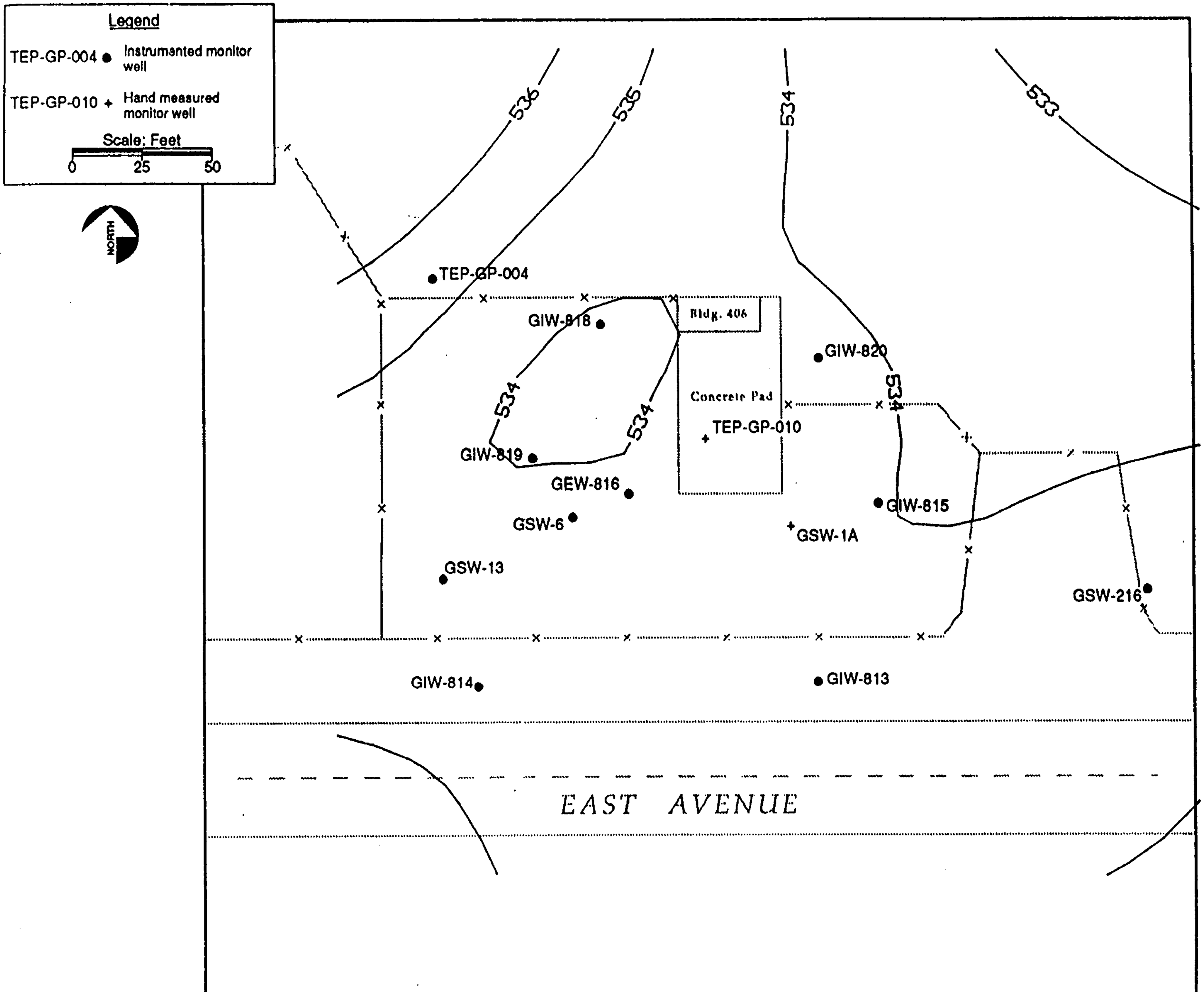


Figure 5. Ground water elevation contours prior to the extraction test of GEW-816 at the Gasoline Spill Area

Weiss Associates

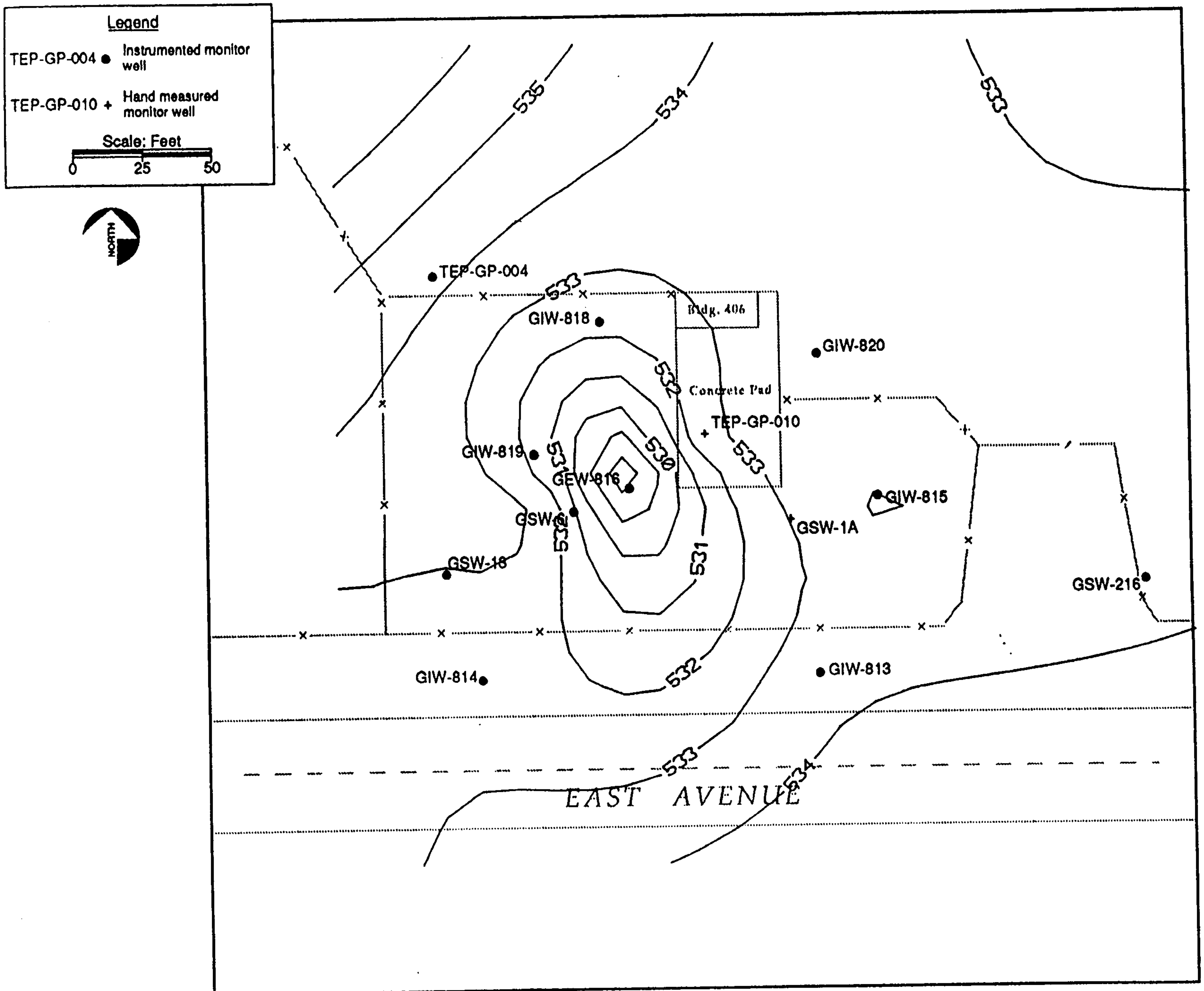


Figure 6. Ground water elevation contours after 180 minutes of pumping at the Gasoline Spill Area

Weiss Associates

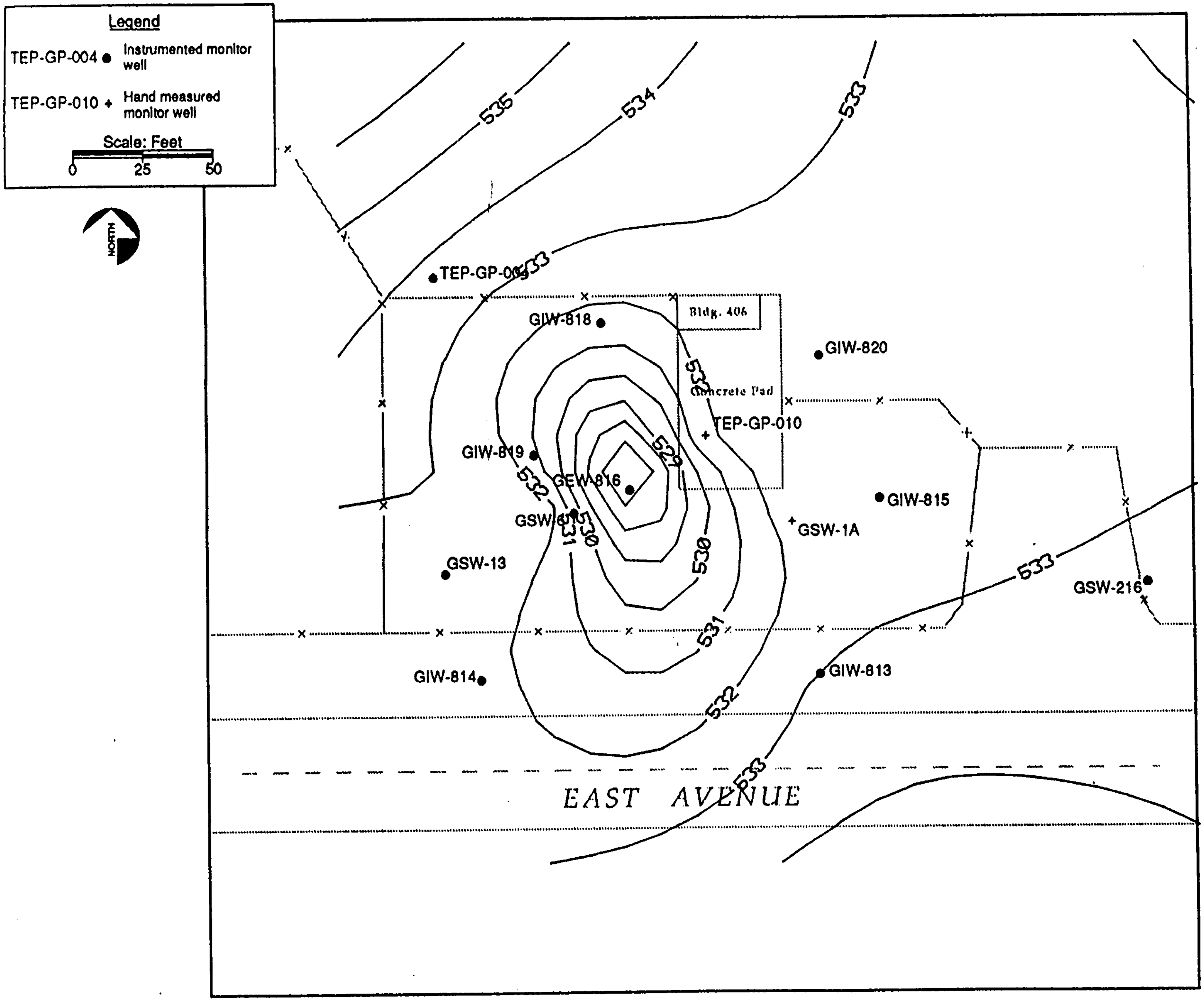


Figure 7. Ground water elevation contours after 410 minutes of pumping at the Gasoline Spill Area

Weiss Associates

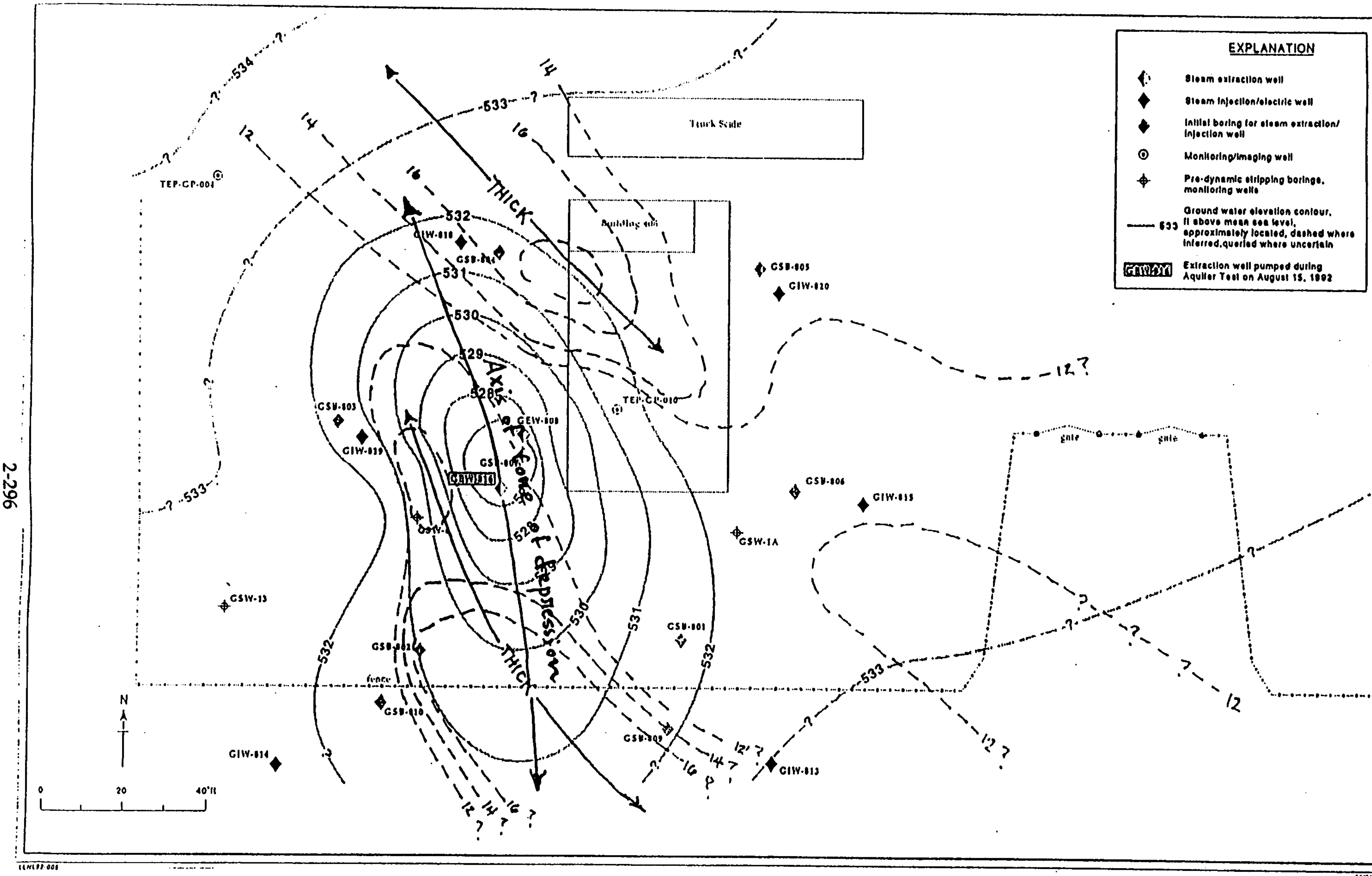


Figure 8. Ground water elevation contour map after 410 minutes of pumping GEW-816 at a constant rate of 39 gpm. Superimposed isopach contours of higher permeability sediments show two offset, northwest-trending thick deposits interpreted as braided stream channel facies. The north-northwest orientation of the cone of depression is considered to represent an average of the orientation of these two thick regions.

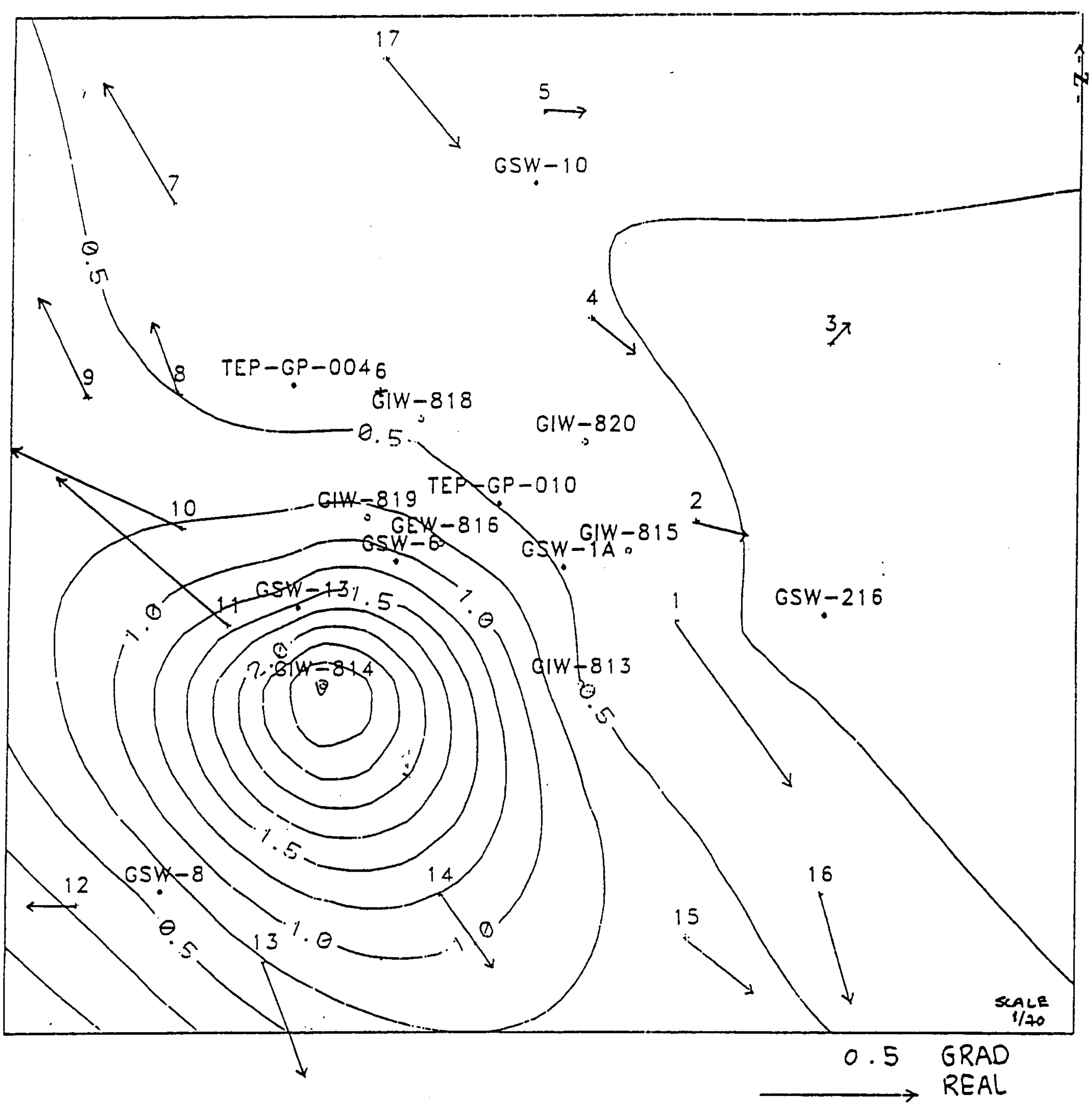


Figure 9. Maximum build-up contours and tiltmeter responses to the GIW-814 injection test.

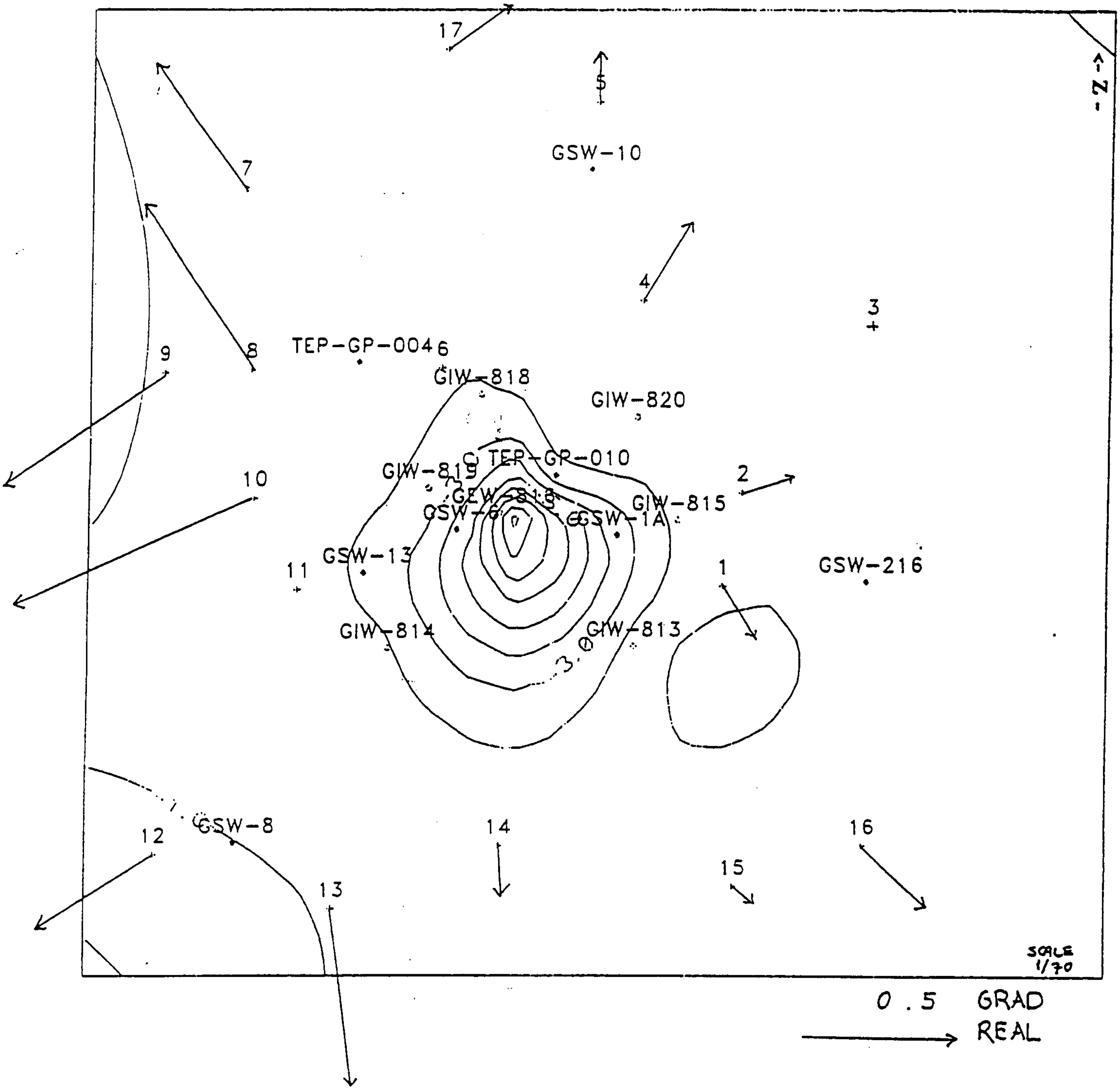


Figure 10. Maximum drawdown contours and tiltmeter responses after pump shut-in following GEW-816 extraction test.

Table 1. Highlights of injection tests conducted at the Gasoline Spill Area, August 6 to 12, 1992.

Well	Screened Interval (ft)	Steam Zone	Injection Time and Date	Injection Rate (gpm)	Injected Volume (gallons)	Comments
GIW-820	112-132	Lower	10:06-11:06 August 6	14	840	
GIW-819	121-141	Lower	14:34-15:34 August 6	20.5	1,230	Water overflowed the casing and entered the LSZ casing, causing the transducer to exceed its range
GIW-813	107-127	Lower	10:46-11:46 August 7	10	600	Added transducers in GIW-813 and GIW-814; removed those in GIW-819 (upper casing), GSW-1A, and TEP-SNL-001
GIW-814	86.5-106.5	Upper	14:24-15:24 August 7	approx. 2	120	Pulled out transducers in GIW-813 and GIW-814 following test
GIW-815	112.5-132.5	Lower	17:32-18:32 August 10	40	2,400	Re-submersed transducers in GIW-813 and GIW-814 prior to this test
GIW-814	121-141	Lower	17:43-18:34 August 11	35	2,100	
GIW-818	120-140	Lower	6:20-7:20 August 12	21.5	1,290	

Table 2. Comparison of results of the GEW-816 extraction test at the Gasoline Spill Area, August 1992.

Well Name	Hydraulic Conductivity (gpd/ft^2)			Transmissivity (gpd/ft)			Storativity	
	Theis	Theis Recovery	Cooper and Jacob	Theis	Theis Recovery	Cooper and Jacob	Theis	Cooper and Jacob
GEW-816	420	1,100	580	4600	12,000	6,400	*	*
GIW-813(L)[1]	570	1,100	750	6,300	12,000	8,200	.0093	.0064
GIW-814(L)	810	1,200	1,200	8,900	13,000	13,000	.0027	.0020
GIW-815(L)	800	1,100	1,100	8,800	12,000	12,000	.0059	.0042
GIW-818(L)	1,000	1,400	1,100	11,000	16,000	13,000	.0023	.0027
GIW-819(L)	920	1,100	950	10,000	12,000	10,000	.0044	.0044
GIW-820(U)	NR	NR	NR	NR	NR	NR	NR	NR
GIW-820(L)	990	1,200	1,100	11,000	14,000	12,000	.0037	.0037
GSW-6	990	1,000	1,100	11,000	11,000	12,000	.0050	.0038
GSW-8	1,000	NA	1,500	11,000	NA	16,000	.0017	.0018
GSW-13	670	900	820	7,300	9,900	9,000	.0038	.0026
GSW-216	450	NA	1,200	5,000	NA	13,000	.0036	.0029
TEP-004	920	1,300	1,200	10,000	14,000	13,000	.0036	.0024
TEP-005	NR	NR	NR	NR	NR	NR	NR	NR
Average:	800	1,100	1,100	8,700	13,000	12,000	4.2E-3	3.4E-3

[1] L = Well screened across the Lower Steam Zone
U = Well screened across the Upper Steam Zone
NR = Well had no response
NA = Not analyzed due to poor data
* = Value was two orders of magnitude higher than values for observation wells

TABLE 3. Summary of previous hydraulic tests conducted in the Gasoline Spill Area wells.

Well No.	Perforated Interval (ft)	Water-bearing Zone Monitored*	Test Type**	T (gpd/ft)	K (gpd/sq ft)	Data Quality***
Wells completed in the Upper Steam Zone						
GSW-2	87-107	First	Slug	240	10	Good
GSW-3	85-105	First	Slug	810	41	Good
GSW-4	86-106	First	Slug	17	0.9	Good
GSW-5	94-104	First	Slug	99	9	Excellent
GSW-403-6	90-110	First	Slug	4	0.2	Good
Wells completed in the Lower Steam Zone						
GSW-1A	155-133	Second	Drawdown	12,000	790	Good
GSW-6	121-137	Third	Drawdown	4,800	310	Good
			Longterm	5,500	350	Good
GSW-7	110.8-123.4	Second	Drawdown	250	23	Excellent
GSW-8	127.5-133	Third	Drawdown	230	38	Good
GSW-13	125-134.5	Second	Slug	110	13	Excellent
			Slug	62	7	Good
GSW-208	108-118	First	Drawdown	440	80	Good
GSW-209	112.8-132.8	First	Drawdown	1,200	120	Good
Wells completed in both steam zones						
GSW-15	20.5-28	First	Drawdown	1,500	190	Good
	38-44	and				
	50-56	Second				
	60-64					
	68-73					
	77-83					
	95-105					
	120-130					
Wells completed in deeper zones						
GSW-12	186.5-191	Fourth	Drawdown	51	11	Fair
GSW-445	155-161	Fourth	Drawdown	43	4	Fair
MW-508	287-305	Seventh	Drawdown	47,000	2,600	Good

* Numbered consecutively downward from ground surface at each extraction location. A water-bearing zone is defined as saturated permeable sediments greater than about 3 ft thick, seperated from other permeable sediments above and below by at least 5 ft of low-permeability sediments.

** Drawdown, denotes 1 hour pumping tests; Longterm, denotes 24 to 48 hour pumping tests; Slug, denotes slug tests.

*** Excellent: High confidence that type curve match is unique. Data are smooth and flow rate well controlled. Good: Some confidence that curve match is unique. Data are not too "noisy". Well bore storage affects, if present, do not significantly interfere with the curve match. Boundary affects can be separated from properties of pumped zone. Fair: Low confidence that curve match is unique. Data are "noisy". Multiple leakiness and other boundary affects tend to obscure the match. Poor: Unique curve match cannot be obtained due to multiple boundaries, well bore storage, uneven flow rate, or equipment problems. Usually the test is repeated.

TABLE 4. Tiltmeter locations and vector data for hydraulic tests, Gasoline Spill Area.

Tiltmeter	LLNL Coordinates		Magnitude of Tilt*							
	East	North	N-S	E-W	N-S	E-W	N-S	E-W	N-S	E-W
			Inj. Test Of GIW-813		Inj. Test Of GIW-814D		Inj. Test Of GIW-815		Inj. Test Of GIW-818	
TLT-GP-001	10561.9	8646.7	2.607E-01	-1.884E-01	1.960E-01	-2.730E-01	9.789E-02	-6.643E-02	7.226E-02	-1.761E-01
TLT-GP-002	10570.9	8693.2	-5.694E-02	1.156E-01	8.819E-02	-2.397E-02	7.969E-02	1.990E-02	-3.429E-02	2.388E-02
TLT-GP-003	10633.7	8775.5	3.192E-01	2.542E-01	3.122E-02	3.542E-02	0.000E+00	0.000E+00	1.480E-01	8.252E-02
TLT-GP-004	10520.6	8788.2	-1.796E-02	3.777E-01	7.901E-02	-5.901E-02	4.505E-02	-3.597E-02	4.939E-02	4.216E-02
TLT-GP-005	10497.5	8887.1	5.947E-02	1.798E-01	6.103E-02	-3.194E-03	-4.395E-02	2.663E-02	9.205E-02	1.915E-01
TLT-GP-006	10422.3	8754.0	-2.528E-01	-2.731E-03	0.000E+00	0.000E+00	0.000E+00	0.000E+00	-1.694E-01	0.000E+00
TLT-GP-007	10324.9	8844.5	0.000E+00	0.000E+00	-1.203E-01	2.041E-01	-4.096E-02	-6.168E-02	-2.296E-02	1.231E-01
TLT-GP-008	10328.6	8753.4	-2.523E-01	3.921E-02	-4.688E-02	1.209E-01	1.047E-02	-6.791E-02	-1.649E-01	-1.704E-02
TLT-GP-009	10286.2	8752.2	-1.091E-01	6.838E-02	-7.958E-02	1.615E-01	3.511E-02	-7.335E-02	-1.247E-01	-2.867E-02
TLT-GP-010	10330.6	8690.9	-1.098E-01	1.220E-01	-2.864E-01	1.319E-01	-1.482E-01	-2.922E-03	-1.692E-01	-1.157E-01
TLT-GP-011	10352.4	8645.4	-5.068E-02	8.911E-02	-2.880E-01	2.483E-01	-1.205E-01	5.654E-02	-5.437E-02	-6.247E-02
TLT-SNL-012	10283.1	8512.5	-2.009E-02	-2.374E-02	-8.204E-02	8.633E-04	-5.466E-02	6.871E-02	3.039E-02	-6.608E-02
TLT-SNL-013	10370.5	8485.2	-2.981E-02	-5.395E-02	7.305E-02	-1.835E-01	3.882E-02	-7.090E-02	3.160E-02	1.674E-02
TLT-SNL-014	10452.0	8516.8	1.203E-02	-6.740E-02	8.734E-02	-1.273E-01	-1.186E-02	-4.285E-02	3.442E-02	-2.786E-02
TLT-SNL-015	10567.8	8496.5	1.349E-01	-4.914E-02	1.192E-01	-9.428E-02	2.201E-01	-7.645E-02	9.569E-02	2.055E-02
TLT-SNL-016	10630.8	8517.0	7.471E-02	-1.221E-02	5.607E-02	-1.820E-01	-5.706E-02	-9.402E-02	1.599E-02	1.387E-02
TLT-GP-017	10423.8	8913.1	6.029E-02	5.314E-02	1.262E-01	-1.512E-01	2.119E-02	-1.285E-01	-6.820E-02	1.003E-01

* Negative values of magnitude indicates tilt to the South or to the West.

TABLE 4. (Continued)

Tiltmeter	LLNL Coordinates		Magnitude of Tilt*							
	East	North	N-S	E-W	N-S	E-W	N-S	E-W	N-S	E-W
			Inj. Test Of GIW-819		Inj. Test Of GIW-820		Ext. Test Of GEW-816			
							Pumping Period		Recovery Period	
TLT-GP-001	10561.9	8646.7	3.026E-01	-1.857E-01	6.441E-01	-8.232E-01	-1.3053E-01	-8.7391E-02	1.2032E-02	-1.7511E-02
TLT-GP-002	10570.9	8693.2	5.624E-02	4.716E-02	1.168E-02	-1.748E-01	-8.6896E-02	-2.3945E-02	1.5074E-02	4.7577E-03
TLT-GP-003	10633.7	8775.5	2.501E-01	-1.593E-01	0.000E+00	0.000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
TLT-GP-004	10520.6	8788.2	-1.805E-01	1.450E-01	1.560E-01	1.665E-01	-3.5236E-02	4.7331E-02	1.6880E-02	2.6924E-02
TLT-GP-005	10497.5	8887.1	1.444E-01	2.032E-01	2.763E-01	-6.596E-02	-9.0112E-02	-8.8121E-02	1.1965E-03	1.8094E-02
TLT-GP-006	10422.3	8754.0	-1.317E-02	-2.894E-05	2.940E-01	3.038E+00	1.8201E-01	5.3264E-03	0.0000E+00	0.0000E+00
TLT-GP-007	10324.9	8844.5	-7.069E-02	-3.298E-02	-4.470E-01	-3.239E-01	-6.7172E-02	1.2680E-02	-3.1336E-02	4.4224E-02
TLT-GP-008	10328.6	8753.4	9.722E-02	1.120E-01	-3.881E-01	-1.261E-01	1.7929E-01	-1.9885E-01	-3.8781E-02	5.8415E-02
TLT-GP-009	10286.2	8752.2	-1.107E-01	1.769E-02	-3.295E-01	-2.566E-01	1.2157E-01	4.0230E-02	-5.5403E-02	-3.8084E-02
TLT-GP-010	10330.6	8690.9	-4.299E-01	9.662E-02	-4.727E-01	-6.430E-02	4.0110E-01	3.8991E-01	-8.3198E-02	-3.7918E-02
TLT-GP-011	10352.4	8645.4	-1.554E-01	7.036E-02	-8.767E-02	-4.090E-02	1.4231E-01	1.2536E-01	0.0000E+00	0.0000E+00
TLT-SNL-012	10283.1	8512.5	4.855E-02	-6.608E-02	5.375E-02	-6.210E-02	5.7684E-02	4.5445E-02	-3.9870E-02	-2.5130E-02
TLT-SNL-013	10370.5	8485.2	3.179E-02	-8.560E-02	2.300E-02	-6.238E-02	1.7758E-02	-1.6013E-02	7.6282E-03	-6.3152E-02
TLT-SNL-014	10452.0	8516.8	-2.265E-02	-7.919E-04	1.166E-02	-1.089E-01	-3.8728E-02	1.1948E-01	9.7151E-04	-1.4379E-02
TLT-SNL-015	10567.8	8496.5	-3.970E-03	6.078E-02	2.287E-01	-3.397E-02	3.3623E-02	5.7031E-02	5.7470E-03	-2.5980E-03
TLT-SNL-016	10630.8	8517.0	2.998E-02	-1.439E-01	-7.205E-02	2.006E-01	-1.0809E-01	1.3441E-01	2.2825E-02	-2.2112E-02
TLT-GP-017	10423.8	8913.1	-3.406E-02	2.030E-02	-8.362E-03	2.510E-01	-1.8588E-03	-1.9334E-01	2.1493E-02	1.7197E-02

* Negative values of magnitude indicates tilt to the South or to the West.

TABLE 5. Monitoring well locations and maximum build-up/drawdown data, Gasoline Spill Area.

Well	LLNL Coordinates East	LLNL Coordinates North	Maximum build-up GIW-813	GIW-814D	GIW-815	GIW-818	GIW-819	GIW-820	Maximum drawdown GEW-816
GEW-816	10451.1	8682.1	0.12	0.75	0.42	0.49	0.56	0.29	-10.47
GIW-813	10517.4	8615.8	0.24*	0.47	0.44	0.12	-	-	-1.49
GIW-814	10396.9	8615.0	0.12	2.84*	0.31	0.22	-	-	-1.88
GIW-815	10539.1	8678.3	0.12	0.38	1.22*	0.25	0.18	0.34	-1.72
GIW-818	10441.4	8740.0	0.08	0.46	0.36	0.98*	0.39	0.32	-2.17
GIW-819	10416.5	8694.4	0.10	0.82	0.30	0.49	1.38*	0.23	-2.46
GIW-820	10518.1	8728.8	0.12	0.32	0.61	0.38	0.22	0.70*	-1.82
GSW-1A	10508.5	8670.7	-	-	-	-	0.24	0.35	-
GSW-6	10430.3	8673.8	0.11	1.07	0.38	0.44	0.69	0.25	-2.81
GSW-8	10322.0	8517.3	0.08	0.58	0.16	0.09	0.11	0.10	-1.01
GSW-10	10494.1	8852.2	-	-	-	-	-	-	-1.44
GSW-13	10384.7	8652.4	0.11	1.42	0.31	0.34	0.62	0.20	-2.20
GSW-216	10631.9	8647.7	0.10	0.22	0.47	0.11	0.10	0.13	-1.25
TEP-GP-004	10381.4	8756.0	0.06	0.39	0.24	0.46	0.38	0.20	-1.64
TEP-GP-010	10478.3	8700.6	-	-	-	-	-	-	-2.26
TEP-SNL-001	10456.1	8518.0	-	-	-	-	0.17	0.14	-

* Maximum build-up at the injection well is assumed to be twice the largest observed build-up in any monitoring well.

- not measured

APPENDIX A

Results of the injection test analyses

TABLE A-1. Hydraulic Analysis Results for Injection Test of GIW-813

Analysis Method	:	Cooper and Jacob (1946)					
Avg. Flow Rate	=	10	gpm				
Avg. Thickness	=	11	ft				
Duration	=	60	min				
Well Name	Interval	K	K	T	Ss	S	Distance
		gpd/ft2	cm/s	gpd/ft	1/ft	-	ft
GEW-816	Lower	NSR	NSR	NSR	NSR	NSR	94
GSW-13	Lower	NSR	NSR	NSR	NSR	NSR	138
TEP-004	Lower	NSR	NSR	NSR	NSR	NSR	195
GIW-818	Lower	NSR	NSR	NSR	NSR	NSR	146
GIW-819	Lower	NSR	NSR	NSR	NSR	NSR	128
GSW-6	Lower	NSR	NSR	NSR	NSR	NSR	105
TEP-005	Lower	NR	NR	NR	NR	NR	178
GIW-813	Lower	NA	NA	NA	NA	NA	0
GIW-814	Lower	NSR	NSR	NSR	NSR	NSR	121
GSW-8	Lower	NSR	NSR	NSR	NSR	NSR	219
GIW-815	Lower	NSR	NSR	NSR	NSR	NSR	66
GIW-820	Lower	NSR	NSR	NSR	NSR	NSR	113
GIW-820	Upper	NR	NR	NR	NR	NR	113
GSW-216	Lower	NSR	NSR	NSR	NSR	NSR	119

NR: No response; NSR: No significant response > 0.2 ft; NA: Not analyzed due to measurement error

TABLE A-2. Hydraulic Analysis Results for Injection Test of GIW-814

Analysis Method	:	Cooper and Jacob (1946)					
Avg. Flow Rate	=	35	gpm				
Avg. Thickness	=	11	ft				
Duration	=	60	min				
Well Name	Interval	K	K	T	Ss	S	Distance
		gpd/ft2	cm/s	gpd/ft	1/ft	-	ft
GEW-816	Lower	1300	6.1E-02	14000	1.6E-04	1.8E-03	86
GSW-13	Lower	720	3.4E-02	8000	2.8E-04	3.1E-03	39
TEP-004	Lower	1500	7.2E-02	17000	2.2E-04	2.4E-03	142
GIW-818	Lower	1400	6.4E-02	15000	1.9E-04	2.1E-03	133
GIW-819	Lower	1200	5.4E-02	13000	1.8E-04	2.0E-03	82
GSW-6	Lower	1200	5.4E-02	13000	6.8E-05	7.4E-04	68
TEP-005	Lower	NR	NR	NR	NR	NR	198
GIW-813	Lower	1000	4.8E-02	11000	2.9E-04	3.2E-03	121
GIW-814	Lower	NA	NA	NA	NA	NA	0
GSW-8	Lower	1200	5.7E-02	13000	1.7E-04	1.8E-03	123
GIW-815	Lower	1500	7.1E-02	17000	2.1E-04	2.3E-03	156
GIW-820	Lower	1600	7.5E-02	17000	2.0E-04	2.3E-03	166
GIW-820	Upper	NR	NR	NR	NR	NR	166
GSW-216	Lower	2200	1.1E-01	25000	2.2E-04	2.4E-03	237
Average	:	1300	6.3E-02	15000	2.0E-04	2.2E-03	

NR: No response; NA: Not analyzed due to measurement error

D:\GASPAD\RES2.WQ1

TABLE A-3. Hydraulic Analysis Results for Injection Test of GIW-815

Analysis Method	:	Cooper and Jacob (1946)					
Avg. Flow Rate	=	40	gpm				
Avg. Thickness	=	11	ft				
Duration	=	60	min				
Well Name	Interval	K	K	T	Ss	S	Distance
		gpd/ft2	cm/s	gpd/ft	1/ft	-	ft
GEW-816	Lower	1600	7.4E-02	17000	6.0E-04	6.6E-03	88
GSW-13	Lower	1700	8.0E-02	19000	2.9E-04	3.1E-03	157
TEP-004	Lower	2300	1.1E-01	25000	3.5E-04	3.9E-03	176
GIW-818	Lower	1700	8.1E-02	19000	3.7E-04	4.1E-03	116
GIW-819	Lower	1800	8.7E-02	20000	4.9E-04	5.4E-03	124
GSW-6	Lower	1700	7.8E-02	18000	4.4E-04	4.8E-03	109
TEP-005	Lower	NR	NR	NR	NR	NR	124
GIW-813	Lower	1200	5.5E-02	13000	1.2E-03	1.3E-02	66
GIW-814	Lower	1700	7.9E-02	18000	2.9E-04	3.2E-03	156
GSW-8	Lower	3400	1.6E-01	37000	2.4E-04	2.7E-03	270
GIW-815	Lower	NA	NA	NA	NA	NA	0
GIW-820	Lower	1700	8.1E-02	19000	5.9E-04	6.5E-03	55
GIW-820	Upper	NR	NR	NR	NR	NR	55
GSW-216	Lower	1200	5.8E-02	14000	4.8E-04	5.3E-03	98
Average	:	1800	8.5E-02	20000	4.9E-04	5.4E-03	

NR: No response; NA: Not analyzed due to measurement error

TABLE A-4. Hydraulic Analysis Results for Injection Test of GIW-818

Analysis Method	:	Cooper and Jacob (1946)					
Avg. Flow Rate	=	21.5	gpm				
Avg. Thickness	=	11	ft				
Duration	=	60	min				
Well Name	Interval	K	K	T	Ss	S	Distance
		gpd/ft2	cm/s	gpd/ft	1/ft	-	ft
GEW-816	Lower	1400	6.4E-02	15000	2.0E-04	2.2E-03	59
GSW-13	Lower	1200	5.7E-02	13000	2.6E-04	2.8E-03	104
TEP-004	Lower	1200	5.5E-02	13000	3.8E-04	4.2E-03	62
GIW-818	Lower	NA	NA	NA	NA	NA	0
GIW-819	Lower	1200	5.5E-02	13000	3.4E-04	3.8E-03	52
GSW-6	Lower	1300	6.2E-02	14000	3.1E-04	3.4E-03	67
TEP-005	Lower	NR	NR	NR	NR	NR	69
GIW-813	Lower	NSR	NSR	NSR	NSR	NSR	146
GIW-814	Lower	1600	7.7E-02	18000	2.7E-04	3.0E-03	133
GSW-8	Lower	NSR	NSR	NSR	NSR	NSR	253
GIW-815	Lower	1300	6.3E-02	15000	3.1E-04	3.4E-03	116
GIW-820	Lower	1200	5.6E-02	13000	3.5E-04	3.8E-03	77
GIW-820	Upper	NR	NR	NR	NR	NR	77
GSW-216	Lower	NSR	NSR	NSR	NSR	NSR	212
Average	:	1300	6.1E-02	14000	3.0E-04	3.3E-03	

NR: No response; NSR: No significant response > 0.2 ft; NA: Not analyzed due to measurement error

D:\GASPAD\RES2.WQ1

TABLE A-5. Hydraulic Analysis Results for Injection Test of GIW-819

Analysis Method	:	Cooper and Jacob (1946)					
Avg. Flow Rate	=	20.5	gpm				
Avg. Thickness	=	11	ft				
Duration	=	60	min				
Well Name	Interval	K	K	T	Ss	S	Distance
		gpd/ft2	cm/s	gpd/ft	1/ft	-	ft
GEW-816	Lower	1600	7.6E-02	18000	4.4E-04	4.9E-03	37
GSW-13	Lower	950	4.5E-02	10000	3.0E-04	3.2E-03	53
TEP-004	Lower	1300	6.1E-02	14000	3.4E-04	3.7E-03	71
GIW-818	Lower	1300	6.3E-02	15000	5.5E-04	6.0E-03	52
GIW-819	Lower	NA	NA	NA	NA	NA	0
GIW-819	Upper	NR	NR	NR	NR	NR	0
GSW-6	Lower	1400	6.4E-02	15000	3.7E-04	4.0E-03	25
TEP-005	Lower	NR	NR	NR	NR	NR	120
TEP-SNL-001	Lower	1900	9.1E-02	21000	2.0E-04	2.2E-03	181
GSW-8	Lower	NSR	NSR	NSR	NSR	NSR	201
GSW-1A	Lower	1600	7.6E-02	18000	4.9E-04	5.3E-03	95
GIW-815	Lower	1800	8.7E-02	20000	3.8E-04	4.1E-03	124
GIW-820	Lower	1600	7.4E-02	17000	4.0E-04	4.4E-03	107
GIW-820	Upper	NR	NR	NR	NR	NR	107
GSW-216	Lower	NSR	NSR	NSR	NSR	NSR	220
Average	:	1500	7.1E-02	17000	3.8E-04	4.2E-03	

NR: No response; NSR: No significant response > 0.2 ft; NA: Not analyzed due to measurement error

TABLE A-6. Hydraulic Analysis Results for Injection Test of GIW-820

Analysis Method	:	Cooper and Jacob (1946)					
Avg. Flow Rate	=	14	gpm				
Avg. Thickness	=	11	ft				
Duration	=	60	min				
Well Name	Interval	K	K	T	Ss	S	Distance
		gpd/ft2	cm/s	gpd/ft	1/ft	-	ft
GEW-816	Lower	990	4.7E-02	11000	2.8E-04	3.0E-03	82
GSW-13	Lower	970	4.6E-02	11000	1.7E-04	1.9E-03	154
TEP-004	Lower	1100	5.0E-02	12000	2.1E-04	2.3E-03	139
GIW-818	Lower	940	4.4E-02	10000	2.6E-04	2.9E-03	77
GIW-819	Lower	970	4.6E-02	11000	2.6E-04	2.9E-03	107
GIW-819	Upper	NR	NR	NR	NR	NR	107
GSW-6	Lower	740	3.5E-02	8100	1.7E-04	1.9E-03	104
TEP-005	Lower	NR	NR	NR	NR	NR	70
TEP-SNL-001	Lower	NSR	NSR	NSSR	NSSR	NSR	220
GSW-8	Lower	NSR	NSR	NSR	NSR	NSR	288
GSW-1A	Lower	1100	5.0E-02	12000	3.1E-04	3.5E-03	59
GIW-815	Lower	1100	5.0E-02	12000	3.6E-04	4.0E-03	55
GIW-820	Lower	NA	NA	NA	NA	NA	0
GIW-820	Upper	NR	NR	NR	NR	NR	0
GSW-216	Lower	NSR	NSR	NSR	NSR	NSR	140
Average	:	970	4.6E-02	11000	2.5E-04	2.8E-03	-

NR: No response; NSR: No significant response > 0.2 ft; NA: Not analyzed due to measurement error

D:\GASPAD\RES2.WQ1

Controlled Distribution List
UCRL-ID-116964 Vol. 1

EM50
Tom Anderson
Dave Biancosino
Gerald Boyd
Clyde Frank
Kurt Gerdes
Joe Paladino
Tom Parker
Caroline Purdy
Mac Lankford
Steve Lien
John Mathur
Bill Schutte
Jef Walker

EM40
Kathy Angleberger
Paul Beam
Tom Crandall
John Lehr

DOE/OK
Mike Brown
J. T. Davis
Roger Liddle
Richard Scott **2 copies**

US EPA TIO
Richard Steimle

Additional Government Copies **20 copies**
Tech Partner Copies **20 copies**

LLNL Distribution
Roger D. Aines
Dorothy J. Bishop
O. Sierra Boyd
H. Michael Buettner
Charles R. Carrigan
Alan B. Copeland
William Daily
Jay C. Davis
Marina Jovanovich
Paula Krauter
Thomas J. Kulp
Kevin C. Langry
Kenrick H. Lee
James Martin
Roger E. Martinelli
J. C. Nelson-Lee
Robin L. Newmark
Abelardo L. Ramirez
Maureen N. Ridley
William H. Siegel
Jerry J. Sweeney
Bruce Tarter
Lee Younker
Jesse Yow **(4 copies)**
John Ziagos

Weiss Associates, Inc.,
Emeryville, CA
Charles Noyes
Everett A. Sorensen

Infraseismic Systems Inc.,
Bakersfield, CA
Roger J. Hunter

Department of Mechanical Engineering,
University of California,
Berkeley, CA
Ron Goldman
Kent M. Kenneally
Kent S. Udell

Health Sciences Research Division,
Oak Ridge National Laboratory,
Oak Ridge, TN
Tye E. Barber
Eric A. Wachter

Materials Science and Minerals Engineering
Department,
University of California,
Berkeley, CA
A. E. Adenekan
T. W. Patzek